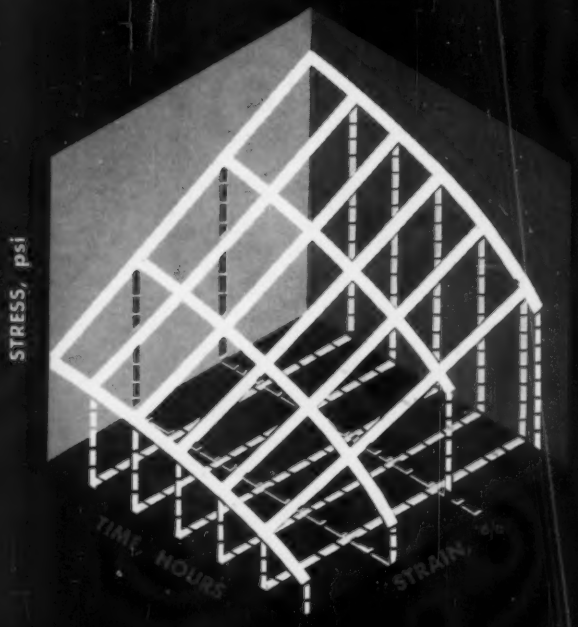
VOL. 16, NO. 11 • NOVEMBER 1960

SPE JOURNAL

The Official Publication of the Society of Plastics Engineers, Inc.

EDITORIAL DEPT.
UNIVERSITY MICROFILMS, INC.
313 N. FIRST ST.
ANN ARBOR, MICH.
14-A

plastics mature as engineering materials



SHORT-TERM TESTS PREDICT LONG-TERM BEHAVIOR — page 1231

SPE COUNCIL ELECTS 1961 OFFICERS — page 1254

Manufacturing vinyls? Keep her happy in the kitchen with

ELASTEX® PLASTICIZERS

Credit nature for the girl. But all the many vinyl products (colored blue) in her modern kitchen have had outside help. They've all been improved through the use of one or another of Allied Chemical's complete line of pure "ELASTEX" Plasticizers.

Take "ELASTEX" 90-P Plasticizer. It's used in the telephone wire cord because of its good electrical properties and volume resistivity . . . in the dish-rack because it gives excellent viscosity to plastisols . . . in the apron and gloves because it leads the phthalates in resistance to soapy water extraction.

"ELASTEX" 18-P improves performance and color stability of the vinyl counter-top and wallpaper. "ELASTEX" 50-B®, a high solvating plasticizer imparting oil and water resistance, and "ELASTEX" 48-P, excellent for general-purpose versatility at attractive cost savings, are used in the vinyl floor tile.

These are the quality "ELASTEX" Plasticizers that make this a better kitchen—a few of the complete line of plasticizers which can upgrade any vinyl product you manufacture. It will pay you to hear the complete story. Call our representative, or contact us direct.

PLASTICS DIVISION

40 RECTOR STREET, NEW YORK 6, N. Y.

Allied Chemical

SCIENCE ENGINEERING

PERFORMANCE

An Invitation to Come to

Washington in January 1961

Society of Plastics Engineers, Inc.

17th ANNUAL TECHNICAL CONFERENCE

January 24, 25, 26, 27, 1961 (Tues. through Fri.)

Shoreham and Sheraton-Park Hotels, Washington, D. C.

AN APPLICATION FOR HOTEL ROOM RESERVATION WILL BE MAILED TO YOU UPON RECEIPT OF YOUR ADVANCE REGISTRATION.

REGISTER NOW

TEAR OUT HERE

TEAR OUT HERE

SPE 17th ANTEC Registration
65 Prospect St., Stamford, Conn.

INDIVIDUAL REGISTRATION FORM
Society of Plastics Engineers, Inc.
SEVENTEENTH ANNUAL TECHNICAL CONFERENCE
January 24, 25, 26, 27, 1961 (Tues. through Fri.)
Shoreham and Sheraton-Park Hotels, Washington, D. C.

Will Your Wife Accompany You to Washington?
☐ Yes ☐ No

MAKE CHECKS PAYABLE TO—
SPE 17th ANTEC

Your Check Must Accompany Your Registration

PLEASE PRINT OR TYPE ALL INFORMATION

NAME (Last) ..... *(First)* ..... *(Initial)* .....
COMPANY .....
ADDRESS .....
CITY ..... *STATE* .....
Hotel and Room No. (Leave Blank) .....

Please Fill Out Below:

YOUR TITLE OR POSITION .....

YOUR COMPANY CLASSIFICATION:

☐ Primary Materials Suppliers
☐ Allied Chemical Suppliers
☐ Heavy Machinery Manufacturers
☐ Light Machinery & Access. Equip.
☐ Processor
☐ End User. Describe .....
☐ Other. Describe .....

REGISTRATION FEES†

SPE MEMBER	☐ $15.00
NON MEMBER	☐ $30.00
STUDENT	☐ $ 5.00

SPECIAL FUNCTIONS

Tuesday Luncheon	☐ $ 4.50
Wednesday Luncheon	☐ $ 4.50
Thursday Banquet	☐ $10.00
Total Enclosed:	$.....

No Refunds After January 20, 1961

This space for Committee Use Only
Date Received: .....
Amount .....
Acknowledged .....

† Includes cost of preprint of papers.

SPI Individual Members May Register at $15.00

17th ANTEC Program Shapes Up

Program innovations, including a special panel of four guest lecturers and technical sessions on newest aspects of the plastics industry, will be featured at the 17th Annual Technical Conference. Preliminary program of the Conference incorporates more than 125 technical papers comprising over 30 separate sessions.

S
P
E
17th
A
N
T
E
C

17th ANNUAL TECHNICAL CONFERENCE

ADVANCE REGISTRATION CAN SAVE YOU VALUABLE TIME AT ANTEC. WITH ADVANCE REGISTRATION, EVERYTHING WILL BE READY FOR YOU UPON YOUR ARRIVAL AT THE ADVANCE REGISTRATION DESK.

Mail this Advance Registration Form and Your Check To:

SOCIETY OF PLASTICS ENGINEERS
17th ANTEC
65 PROSPECT STREET
STAMFORD, CONNECTICUT

U.S. BORAX RESEARCH CORPORATION
412 CRESCENT WAY
ANAHEIM, CALIFORNIA

☐ Please send literature on USB epoxy resin curing agents.

☐ Include samples.

NAME _____

COMPANY _____

ADDRESS _____

CITY _____ ZONE ____ STATE _____

NEW

USB CURING AGENTS *for epoxy resins*

LONG POT LIFE

LOW TOXICITY

IN LIQUID FORM

EASY TO HANDLE

You get big advantages from USB epoxy resin curing agents!

LONG POT LIFE — several weeks to several months.

LOW TOXICITY — no dermatitis cases on record in handling these materials over extended periods.

LIQUID FORM — allows easy handling and ready miscibility with the resins. Curing can be done at relatively low temperatures — 2 hours @ 175°F.

Resins cured with USB curing agents offer these desirable properties:

- **HEAT DISTORTION TEMPERATURES UP TO 130°C.**
- **EXCELLENT ELECTRICAL PROPERTIES.**
- **WATER AND BLUSH RESISTANCE.**
- **RESISTANCE TO AQUEOUS ACID AND BASE.**
- **CLASS B RESINS CAN BE FORMED FOR LAMINATING.**

USB epoxy resin curing agents are readily available in quantities up to multi-drum lots. Mail the coupon to bring samples and descriptive literature.

U.S. BORAX

U.S. BORAX RESEARCH CORPORATION
412 CRESCENT WAY, ANAHEIM, CALIFORNIA

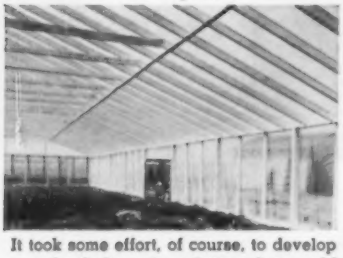
TENITE DEVELOPMENT LABORATORY

DOINGS AND FINDINGS

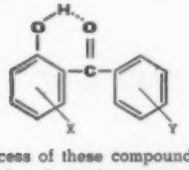
GREENHOUSES, SUNSHINE, AND STABILIZERS

Have you ever potted a plant or seeded a small patch of ground, and experienced the thrill of watching it blossom out? To raise the more exotic flowers, to extend the growing season, or simply to find more room when the grower's better half won't put up with any more plants in the house, the true enthusiast builds himself a greenhouse.

Now that polyethylene is available in weather-resistant formulations, horticulturists can put up a simple wooden frame and cover it with inexpensive, but surprisingly durable, polyethylene film. As might be expected, polyethlene-covered greenhouses are also becoming popular with the commercial grower.



It took some effort, of course, to develop a polyethylene formulation that could withstand the destructive ultraviolet rays in sunlight and yet permit the visible ones necessary for healthy plant growth to shine through. Eastman plastics laboratories found that non-pigmenting compounds having the general configuration shown here provided polyethylene with the necessary protection when dispersed in the material.



The success of these compounds in stabilizing the plastic lies not so much in their ability to absorb ultraviolet radiation as in their ability to dispose of it in easy stages, at no time releasing a harmful amount of energy to surroundings.

Although a number of compounds having the chelate structure shown above make satisfactory stabilizers, it was found by measuring the nuclear magnetic resonance spectra of these compounds (with a nuclear magnetic spectrometer—what else?) that the X and Y groups which strengthened the electronic density within the carbonyl group and decreased it within the hydroxy group improved the ability of the compound to rid itself harmlessly of the absorbed ultraviolet energy. The compound that had the configuration which proved to protect polyethylene best is now incorporated in certain formulations of Tenite polyethylene to make them unusually resistant to sunlight and weathering.

In addition to weather-resistant Tenite Polyethylene, Eastman also offers highly weather-resistant formulations of Tenite Polypropylene and Tenite Butyrate. For further information, drop us a line.

NEW SIGNS FOR OUR TIMES

If you've been traveling over the country on your vacation and have observed weathered and rusty signs, you'll be happy to learn that the day is at hand when signs can be lastingly bright and legible. No longer need sign lettering wear dim and become unreadable. In fact, producing a sign no longer requires paint. The thing that makes all this possible is a new two-layered, weather-resistant butyrate plastic sheet which we have developed ready for commercialization by custom extruders.

This duplex sheet is produced by a simple butyrate-to-butyrate sheet-coating operation worked out by the Eastman plastics laboratories. Although it has two layers of contrasting color, the sheet is a single, uniform thickness, with pigmentation change at its interface.

Shown here is a sign made from duplex sheet. First, the sheet was "drape-formed" over a mold which raised the lettering on the sign face. Then, surfaces of the raised letters were wet-sanded to remove their upper layer of plastic. This permitted the contrasting color of the plastic below to show through. Since the upper layer of a typical 100-mil sheet is only 10 mils, sanding takes just about 5 seconds. Water sprayed on during the sanding operation keeps down the temperature of the plastic and prevents it from gumming the abrasive.

We market only the resin and do not ourselves commercially extrude or fabricate sheet. But if you have some questions about duplex sheet, we will try to answer them. Write to Eastman Chemical Products, Inc., Plastics Division, Kingsport, Tennessee.

TENITE®

plastics by Eastman

Society of Plastics Engineers, Inc.

An international scientific and educational organization of more than 8,000 individual members devoted to the development and dissemination of technical information in the fields of research, design, development, production and utilization of plastics materials and products. The Society is incorporated under the laws of the State of Michigan.

Executive and Business Offices
65 Prospect St.
Stamford, Conn.

Officers of the Society

George W. Martin, *President*
Frank W. Reynolds, *1st Vice President*
Haiman S. Nathan, *2nd Vice President*
James R. Lampman *Secretary*
Joseph B.Schmitt, *Treasurer*
Thomas A. Bissell, *Executive Secretary*

All correspondence relative to business matters, meetings of the Society, membership, advertising etc., should be addressed to the business offices listed above.

•

Members should notify the business offices at least 30 days in advance of contemplated changes in address.

•

Membership in the Society is available to qualified individuals. Inquiries should be addressed to the business office.

•

Membership in the Society is extended to individuals who by previous training or experience or by present occupation qualify them to carry out the objective of the Society. The privileges of membership are designed to enhance the professional standing of the individual member by encouraging participation in scientific and technical programs and professional activities; by developing close personal contacts and acquaintanceship among members; and by providing an opportunity to administer the local and national activities of the Society.

•

Neither the Society of Plastics Engineers, Inc., nor the SPE Journal is responsible for the views expressed by individual contributors either in articles published in the Journal or in technical papers presented at meetings of the Society.

Non-Member Subscription Rates

*DOMESTIC		**FOREIGN	
1 Year	$ 6.00	1 Year	$10.00
2 Years	11.00	2 Years	18.00
3 Years	15.00	3 Years	20.00

**Single Issue .65 **Single Issue 1.50 *Single issues older than 6 months are charged at $1.00, and single copies of the Roster Issue at $10.00.*

• **The SPE Journal is Published at 215 Canal St., Manchester, N. H. Address changes, undeliverable copies and orders for subscriptions should be sent to 65 Prospect St., Stamford, Conn.**

SPE JOURNAL

Editor
Melvyn A. Kohudic

Editor Emeritus
Dr. Jesse H. Day

Layout and Production
Leo Cooper

Editorial Assistant
A. L. Norvell

Feature Editors

Moldmaking
Ernest J. Cosgrove

Standards for Plastics
Dr. Frank W. Reinhart

Polymer Science
Dr. Irvin Welock

Reinforced Plastics
George Lubin

Society Action
Thomas A. Bissell

Speaking of Extrusion
B. H. Maddock

PAG Progress
Frank W. Reynolds

SPE Publications Committee

Maurice F. Maloney, *Adm.*
Dr. Alex Socher, *Chmn.*
Dr. Raymond F. Boyer
Dr. Jesse H. Day
Dr. Herman F. Mark
Frank A. Martin
Eugene C. Quear
Dr. Frank W. Reinhart
Irvin I. Rubin
Dr. Sidney J. Stein
Parke Woodworth

Editorial Advisory Board

Dr. Frank W. Reinhart *Chmn.*
Robert W. Barber
Dr. Luther Bolstad
Edward F. Borro, Sr.
Benjamin S. Collins
William Croll
Edward J. Fitzpatrick
Russell M. Houghton
Dr. Herman S. Kaufman
John P. Lombardi
Thomas F. McLaughlin
Robert E. Monica
Jules Pinsky
Robert D. Sackett
Edward W. Vaill
Frederick Wehmer

Circulation Manager
Lewis A. Bernhard

Advertising Manager
Leon R. Noe

Managing Assistant
Jane W. Lazarus

Advertising Representatives

Eastern
Leon R. Noe
65 Prospect Street
Stamford, Conn.
Fireside 8-7528

West Coast
Thompson & Clark Co.
681 Market St.
San Francisco 5, Calif.
DOuglas 2-8547

Ohio-Eastern Michigan and Western Pennsylvania
Raymond B. Mooney & Associates
6832 Graystone Drive
Sylvania, Ohio
TUrner 2-6385

and
6000 Sunset Blvd.,
Rm. 202
Hollywood 28, Calif.
HOllywood 3-4111

Upper Midwest
M. B. Bock & Assoc.
654—Baker Bldg.
Minneapolis 2, Minn.
FEderal 6-5357

Central-Midwest
R. D. Henriquez
549 W. Washington Blvd.
Chicago 6, Ill.
CEntral 6-1626

• *Entered as second-class matter at the Post Office at Manchester, New Hampshire. Accepted at special postal rate provided in paragraph (d-2), Sec. 34.40, P.L. and R., of 1918.*

• *Copyright by the Society of Plastics Engineers, Inc., 1960. Reproduction in whole or part without written permission is strictly prohibited.*

Member of the Audit Bureau of Circulations

AUDITED PAID CIRCULATION ABC

plastics engineering trends of technical *significance*

SPE Journal Newsletter 1193

SPECIAL FEATURE—A Pattern for Plastics Education
James E. Parkhill, Chairman, Ontario Section Education Committee
How a study course in plastics was set up 1199

SPE Journal Features

Speaking of Extrusion—Technical Upgrading of Process Line Operators
Reader comments and ideas invited on maintenance problems 1207

Polymer Science—Ultimate Tensile Properties of Amorphous Polymers
Thor L. Smith, Stanford Research Institute
Effect of experimental conditions, physical state, and structure on ultimate stress and elongation 1211

Reinforced Plastics—A Working Bibliography of Reinforced Plastics
Harry Raech, Jr., Norair Div., Northrop Corp.
Selected reviews of books in the field of reinforced plastics 1221

Technical Articles

Check box for later reference

☐ **Designing Thermoplastic Structural Components**
W. D. Harris and W. W. Burlew, Dow Chemical Co., and F. McGarry, Massachusetts Institute of Technology
Two methods for predicting load-carrying ability of thermoplastics 1231

☐ **Stress Relaxation and Creep Measurements of Thermoplastics**
R. L. Bergen and W. E. Wolstenholme, Naugatuck Chemical Co., Div. of United States Rubber Co.
Methods for obtaining long-term data from short-term tests 1235

☐ **Effect of Amine-Cured Epoxy Resins on the Stability of Trinitrotoluene**
Hugh C. Anderson, Naval Ordnance Laboratory
Studies aid in increasing compatibility of adhesives in contact with explosives 1241

☐ **Testing Resin-Fiber Laminates**
A. P. Penton, Convair Div., General Dynamics
Picture-frame loading device tests shear properties of reinforced plastics 1246

☐ **Quality Control Check-List for TFE Resins**
P. E. Thomas, E. I. du Pont de Nemours & Co., Inc.
In-plant procedures for quality control for fabricated fluorocarbon resin parts 1248

☐ **Adhesives for PVC Shoes**
R. J. Carey, Compo Shoe Machinery Corp.
Plasticizers key ingredients for adhesives for PVC shoes 1253

News of SPE

Society Action—Reynolds to Lead SPE in 1961 1254

1961 Officers Elected at October 18 Council Meeting

Departments

Editorial 1187
Technical Meetings Calendar 1276
Section News 1264
About Members 1260
Plastics Around the World 1272
New Books 1271
Employment and Service Guide 1277
Advertisers' Index 1278

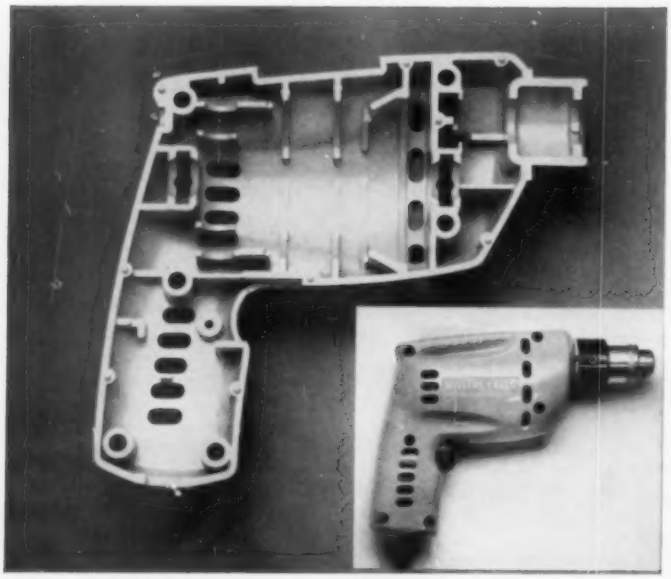
The Cover

Three dimensional drawing enables design engineers to determine limits of usefulness of thermoplastics as structural members. For complete formulas, sample problems, see page 1231.

DU PONT
Better Things for Better Living
. . . through Chemistry

PLASTICS PROSPECTS

Expanding use of ZYTEL® opens new market opportunities for molders



New Millers Falls drill housing of ZYTEL® brings design improvements

The insulating properties of ZYTEL nylon resins make possible a drill housing that helps protect against shock hazards. In addition, this rugged and durable housing of ZYTEL is 20% lighter in weight than a comparable housing of aluminum. It is self-extinguishing. It stays comfortable to the touch in hot or cold weather, even after prolonged use. The two halves of the drill housing are molded quickly and easily by the molder. The choice of ZYTEL 31 assures good dimensional stability of the moldings, and permits a perfect match of each half for screw inserts, assembly and flange matings. No machining is necessary.

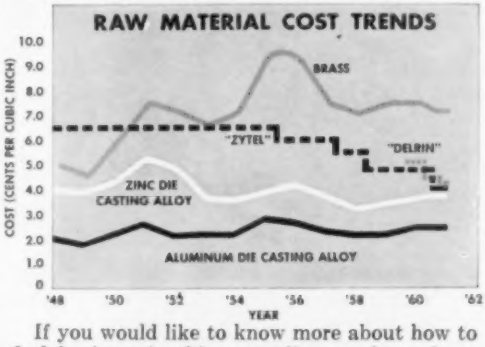
The manufacturer, Millers Falls Company, of Greenfield, Mass., reports that extensive field tests of the new drill have proved its excellent service life. The new drill also has a black collar and lock switch made of Du Pont DELRIN® acetal resin—chosen for its exceptionally good dimensional stability.

The need for improved product performance and lower costs is turning more and more manufacturers toward plastics as replacement materials for metals. Engineering plastics such as DELRIN® acetal resin and ZYTEL® nylon resins are opening vast new sales opportunities for injection molders.

The story of the new Millers Falls drill housing, at left, is a case in point. The total opportunities for the economical use of ZYTEL in the field of small power tools have hardly been tapped. In sporting goods, plumbing fixtures, mechanical applications, hardware items and many other areas, the growth of applications of ZYTEL is rapid, and offers molders opportunities for an expanded volume of business.

As prices of DELRIN and ZYTEL have continued to drop and those of aluminum, zinc, brass and other metals have continued upward, the market for parts of plastic has expanded. The chart shows these materials-cost trends.

Since parts molded of plastic require little or no finishing in comparison with costly finishing operations on metal, even when only moderate finishing is required, the completed-part cost in plastic is often lower. When the properties of the plastic fit, the business is there.



If you would like to know more about how to find business in this expanding market, please write to: E. I. du Pont de Nemours & Co. (Inc.), Dept. KK-11, Room 2507Z, Nemours Building, Wilmington 98, Delaware.

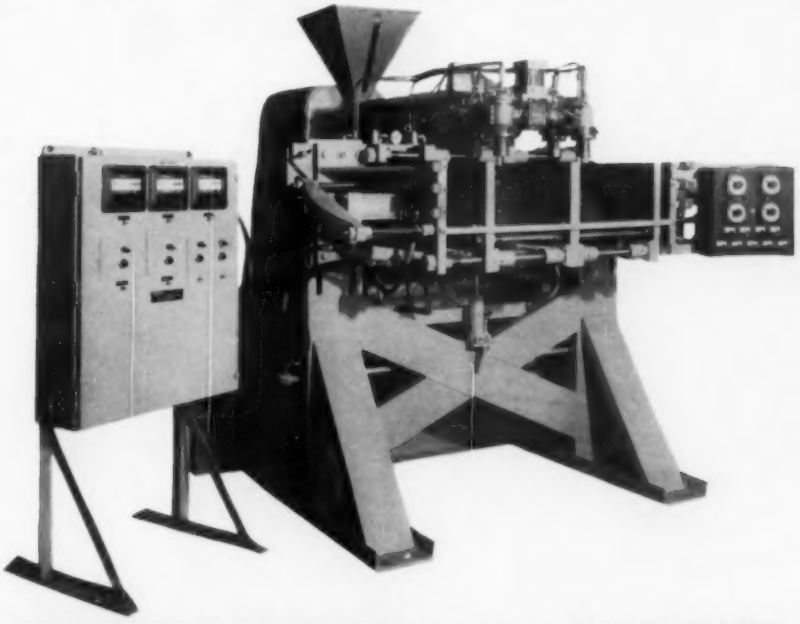
In Canada: Du Pont of Canada Limited, P. O. Box 660, Montreal, Quebec.

POLYCHEMICALS DEPARTMENT

Du Pont's problem-solving engineering materials:

ALATHON® polyethylene resins | DELRIN® acetal resin | LUCITE® acrylic resins | ZYTEL® nylon resins

TRICO BLOW MOLDING MACHINES



THREE MODELS TO CHOOSE FROM

MODEL 885

Platen size: 8″ x 8″

Air operation

Up to 2800 Lbs. Clamping Pressure

2 or 4 nozzle

Machine Operation: manual or automatic

MODEL 1216A

Platen size: 12″ x 16″

Hydraulic operation

12,000 Lbs. Clamping Pressure

2 or 4 nozzle

Machine Operation: manual or automatic

MODEL 1824A

Platen size: 18″ x 24″

Hydraulic operation

30,000 Lbs. Clamping Pressure

2 or 4 nozzle

Machine Operation: manual or automatic

ACCUMULATORS AVAILABLE ON ALL MODELS. EQUIPMENT MAY BE ADAPTED FOR SPECIAL BLOW MOLDING PROBLEMS

For additional information, call or write:

ACME MACHINERY & MFG. CO., INC.

Exclusive Sales Agents

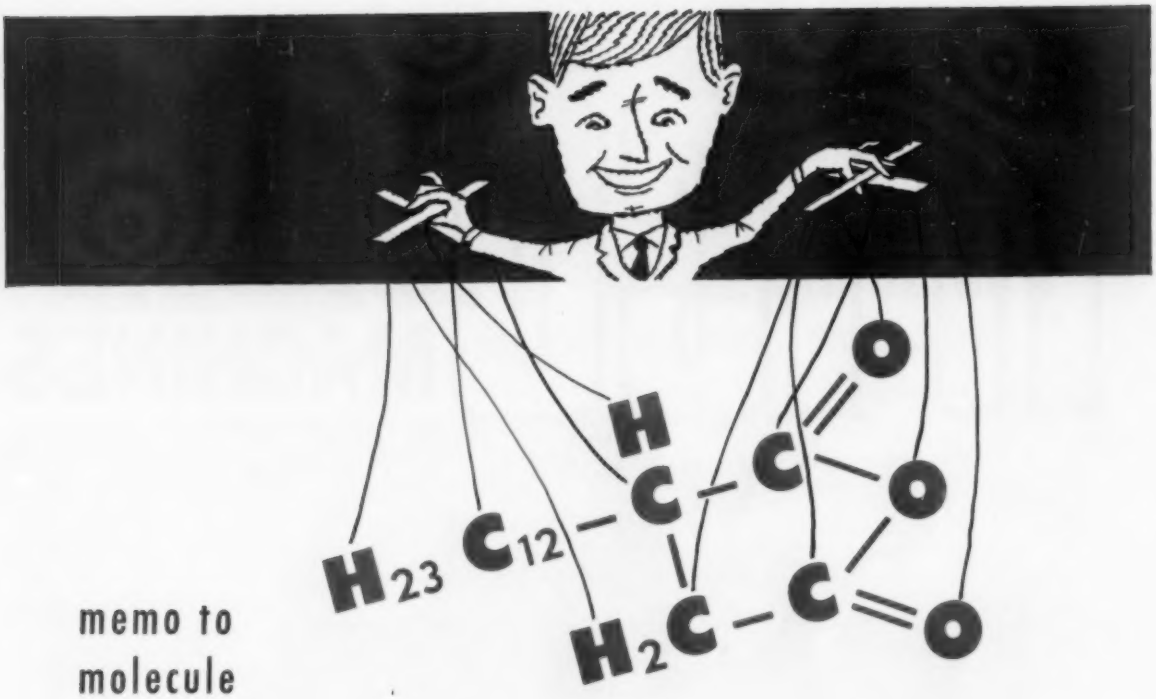
500 Saw Mill River Road
Yonkers, N. Y.
YOnkers 5-0900

102 Grove Street
Worcester, Mass.
PLeasant 7-7747

TRICO MANUFACTURING CORP.

484 Bridgeport Ave., Shelton, Connecticut
Phone: WAverly 9-1451

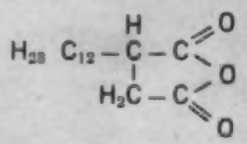
ALSO SPECIALIZING IN BLOW MOLDING DIES



memo to
molecule
manipulators

about . . . **National®**
DODECENYLSUCCINIC ANHYDRIDE

Here is a long-chain bifunctional alkenylsuccinic anhydride with an interesting configuration on which to build new intermediates and end products.



Note particularly the three points for addition reactions as steps toward new end products. Note also the positions of the oil-soluble alkenyl group and the hydrophilic reactive anhydride end.

DODECENYLSUCCINIC ANHYDRIDE finds use as an epoxy curing agent, polyester and alkyd resin intermediate, corrosion inhibitor, etc. Many other uses are cited in the literature.

DODECENYLSUCCINIC ANHYDRIDE is one of a long line of dibasic acid anhydrides produced by National from basic raw materials wholly integrated within the Allied Chemical group. It is amply available in commercial quantities.

WRITE FOR TECHNICAL BULLETIN I-8

This six-page technical bulletin gives chemical and physical properties, principal reactions, infra-red absorption spectrogram, viscosity curve, suggested uses and a bibliography. A copy of this bulletin and a liberal working sample will be sent on request. Our Development Chemists will be glad to provide additional assistance to those whose work may lead to volume use of National Dodecenylsuccinic Anhydride.

NATIONAL ANILINE DIVISION
40 RECTOR STREET, NEW YORK 6, N. Y.
Atlanta Boston Charlotte Chicago Dallas Greensboro
Los Angeles Philadelphia Portland, Ore. Providence San Francisco
In Canada: ALLIED CHEMICAL CANADA, LTD.,
1450 City Councillors St., Montreal 2 100 North Queen St., Toronto 18
Distributors throughout the world. For information:
ALLIED CHEMICAL INTERNATIONAL • 40 Rector St., New York 6, N. Y.

Allied Chemical

EDITORIAL

MOVING THE CLOCK AHEAD

Another *"First"* for SPE JOURNAL

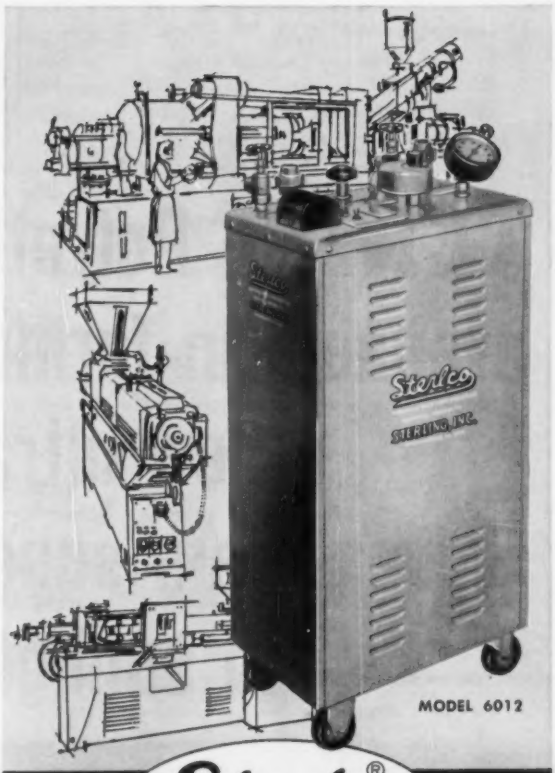
We're starting the New Year right with a unique service for current Classified Advertisers—one which, to our knowledge, has not been similarly undertaken by any publication.

Beginning with the January ANTEC issue, the necessary, but regrettable time lag between placement of classified ads and their publication will be reduced to a basic minimum. Here's how. Upon receipt of your insertion request, a card will be sent to you to fill out and return to us. It will include three general categories, from which you will choose the one which best describes your advertised position. As soon as this card is returned to us, we will put you in touch with the available prospects whose ads have not yet been published. However, for your protection as well as our own, no instructions will be accepted, unless transmitted via the card we have mailed to you. Subsequently, your sole obligation will be to notify us when you wish your name (or that of your company) to be removed from our Availability File.

On "Positions Wanted' ads placed by SPE members in good standing, there will be no charge. A modest fee of $5 to cover costs of mailing and clerical work will be added to our low rates for "Positions Open" ads.

As in the past, no resumes will be kept on file. Our function is purely that of intermediary. If we can be an effective intermediary, our mission will be accomplished.

The new service is a result of a recently conducted survey of our classified advertisers. A 40% response indicated by an overwhelming maiority (nearly 90%) that they favor their availability (or job) being made known prior to publication in the same way as upon publication. To this end, we proudly introduce the expanded service. In our continual strivings to make SPE JOURNAL more valuable to its readers, we hope you will be pleased with this augmented service. It is our belief that it will stimulate "traffic" in our Employment Guide pages, so that even those who do not wish to participate in the new plan will find still more potential prospects therein.

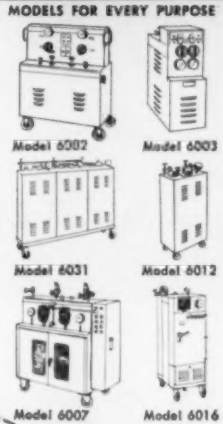


MODEL 6012

Sterlco®

SINGLE ZONE TEMPERATURE CONTROL FOR INJECTION MOLDING, VACUUM FORMING, EXTRUDING

MODELS FOR EVERY PURPOSE



Model 6012 is especially designed for plastic forming processes where a single, stabilized water temperature is required for the control of mold or calendar roll temperatures. Among the outstanding features of this unit are fast reaction to temperature change, low water capacity, high circulating velocity. While normal operation position is vertical, this model can be furnished to operate in any one of 4 horizontal positions — at no additional charge.

Leaders in temperature control since 1916

Sterling inc.

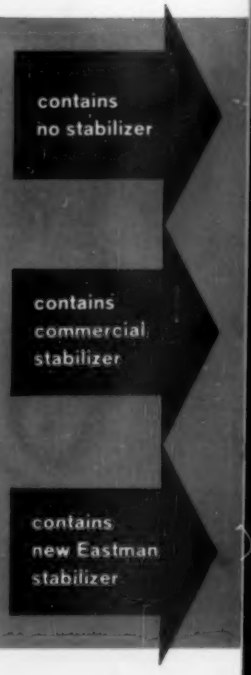
5202 W. Clinton Ave., Milw. 23, Wis.

Industrial Control Division

NEW FROM EASTMAN

TENITE Polyethylene is now available in formulations containing a new ultraviolet inhibitor that gives them superior resistance to sunlight and weathering

- Exposure tests prove the superior durability of polyethylene film, sheet and moldings stabilized with new Eastman inhibitor
- Effectiveness is not impaired by molding or extruding temperatures up to 600°F.
- Stabilized film retains a high degree of clarity, flexibility, smoothness and toughness
- The new inhibitor markedly extends the useful life of polyethylene film for greenhouse glazing...silo, storage and machinery covers



TENITE SALES OFFICES:
Atlanta, Chicago, Cleveland, Dallas, Dayton, Detroit, Greensboro (N. C.), Kansas City (Mo.), Leominster (Mass.), New York City, Philadelphia, Rochester (N. Y.), St. Louis, Toronto.

WEST COAST REPRESENTATIVE:
Wilson & Geo. Meyer & Company, San Francisco, Los Angeles, Portland (Ore.), Seattle.

New, specially stabilized Tenite Polyethylene formulations for extrusion into thin, transparent, weather-resistant film are now available from Eastman. Incorporated in the resins is a new non-pigment ultraviolet inhibitor developed by Eastman chemists.

The effectiveness of the inhibitor is not impaired by molding or extrusion temperatures as high as 600°F. This, too, represents an improvement over polyethylene formulations stabilized with previously available ultraviolet inhibitors.

Film only 5 mils thick, extruded from a typical Tenite Polyethylene formulation containing the new inhibitor, has withstood two years of continuous outdoor weathering with little loss of strength. Results of tests on the exposed film show that it retained more of its original properties after 24 months' exposure than film of unstabilized polyethylene retained after only 12 months' exposure.

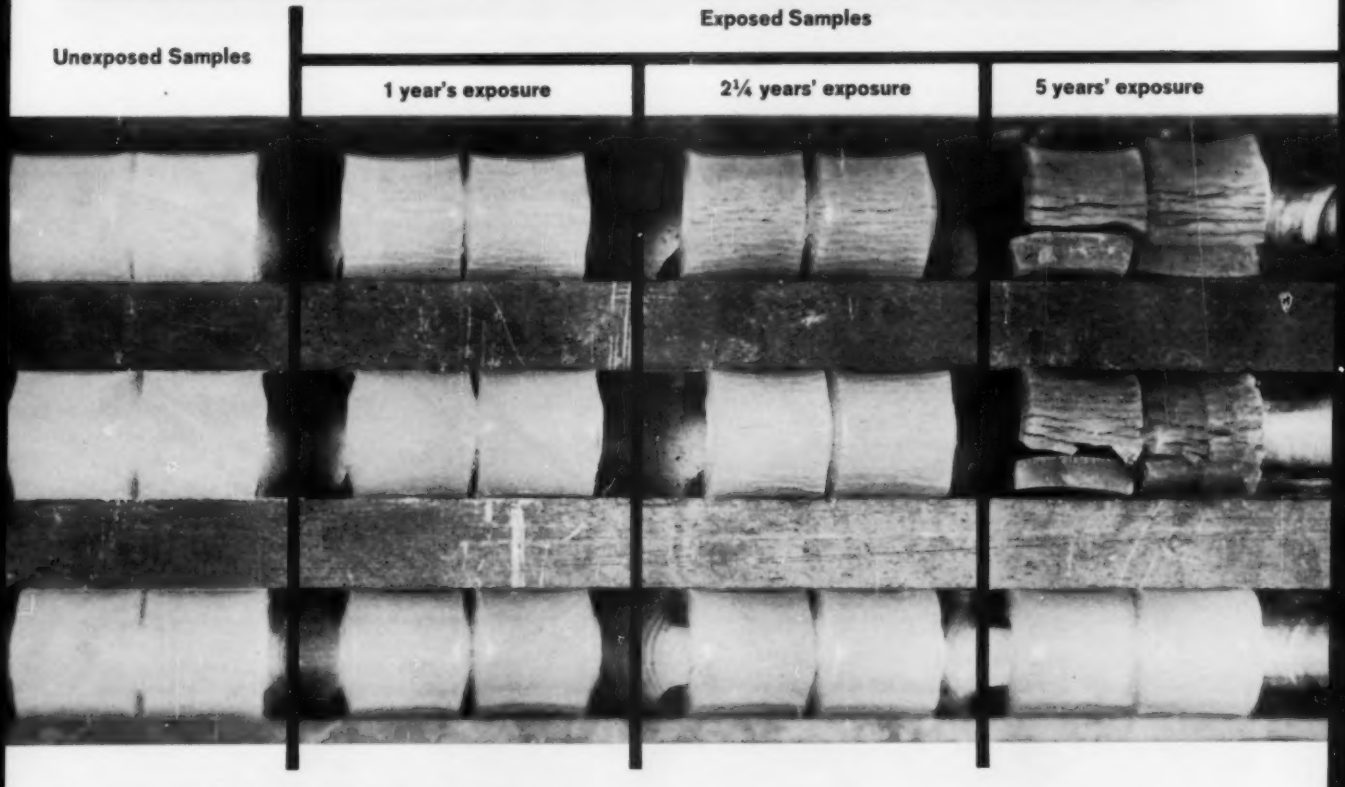
Specifically, the stabilized film retained a high degree of original clarity, and remained smooth, pliable and tough.

The demonstrated superior performance of the new stabilized resins greatly extends the usefulness of polyethylene film in such outdoor applications as glazing for greenhouses, and protective covers for silage, machinery and other outdoor-stored materials.

Eastman also supplies a stabilized Tenite Polyethylene formulation for extrusion of sheet 50 mils or thicker as well as for injection molding of heavier sections. In weathering tests recently completed, 50-mil sheet of this material retained 88% of initial elongation after three years of outdoor exposure. Heavier sections (125 mils), weathered under stress, still retained their good appearance after five years. Such results indicate that polyethylene sheet and molded parts can be expected to resist the elements two to three times as long as was previously possible.

For further information on Tenite Polyethylene formulations stabilized with the new ultraviolet inhibitor, contact any of the Tenite sales offices, or write Eastman Chemical Products, Inc., subsidiary of Eastman Kodak Company, Kingsport, Tennessee.

WEATHERABILITY OF STRESSED TENITE POLYETHYLENE



Pictures are better than words!

Here is an unretouched photograph showing a test rack of stressed molded specimens after 5 years of continuous exposure in Tennessee. Specimens were 125 mils thick and were molded from a typical base formulation of Tenite Polyethylene. The photograph forcefully illustrates the effectiveness of Eastman's new ultraviolet stabilizer.

TENITE®
POLYETHYLENE
an Eastman plastic

IF PHENOLICS CAN DO IT, **PLENCO** CAN PROVIDE IT—AND DOES—FOR **SUNBEAM**

Sunbeam's "CONTROL-CENTER" HANDLE
KEEPS CALM, COOL, AND RESPECTED . . . THANKS TO

PLENCO

PHENOLIC MOLDING COMPOUNDS

"IF you can't stand the heat," according to an old political axiom, "stay out of the kitchen."

Housewives all over the country know that Sunbeam Corporation, Chicago, Ill., builds modern cooking appliances with handles that not only can "stand the heat", but help make a woman's daily tour of duty in the kitchen more pleasurable and productive.

Among these appliances, the Sunbeam Automatic Electric Frypan has long led in a new concept of rangeless meal preparation. Outstanding Sunbeam Frypans feature controlled even heat determined by a dial housed in the handle itself. Phenolic-molded, the handle stays cool and attractive. To make sure it does, Sunbeam engineers use a Plenco molding compound (Plenco 423) that provides the ideal combination of required properties: heat resistance, electrical insulation, dimensional stability, moisture and acid resistance, plus production factors assuring ease and economy.

Ready-made or specially made, there's a wide range of Plenco molding compounds available. They're use-proved in a number of additional applications by Sunbeam and by Sunbeam's Oster Division . . . as well as countless other successful applications in industries as varied as are the compounds themselves. Want to learn more about the advantages for *you* with phenolics by Plenco? We're ready to show you.

PLASTICS ENGINEERING COMPANY
Sheboygan, Wisconsin

Serving the plastics industry in the manufacture of high grade phenolic molding compounds, industrial resins and coating resins.

New member of the Oncor® family–23A...

A unique pigment for flame retardance in halogenated plastics and paints

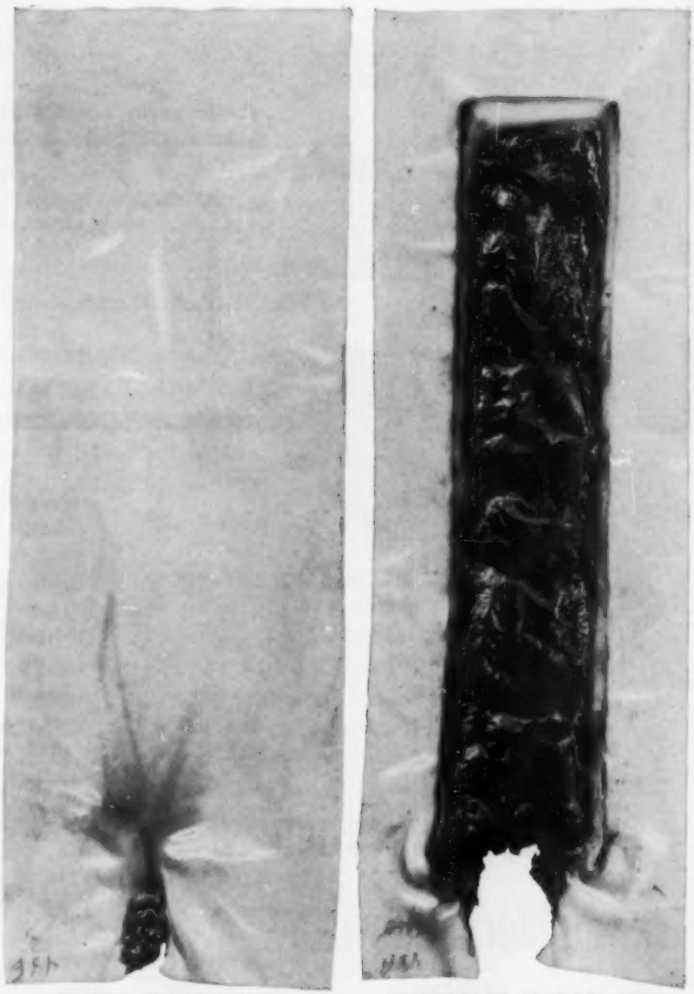
Never before has there been a pigment like ONCOR® 23A, developed especially for compositions based on halogenated resins. This pigment is composed of an inert silica core of low specific gravity, and has a surface layer of antimony oxide fused to the core.

Here's a quick run-down on the outstanding features of this significant new ONCOR pigment:

1. **Effective Flame Retardance** – ONCOR 23A pigment compares favorably with conventional antimony oxides in flameproofing efficiency in halogen-containing resins for plastics and paints. In tests on vinyl films, ONCOR 23A pigment has given equivalent flame resistance compared to conventional antimony oxide, on an equal weight basis.
2. **Low Tinting Strength** – ONCOR 23A pigment has a low and uniform tinting strength. In vinyl film tests, tinting strength consistently measures between 60% and 65% of a conventional antimony oxide standard. This allows most effective use of colorants.
3. **Low Specific Gravity** – Because of its special physical structure, ONCOR 23A pigment has a lower specific gravity than regular antimony oxides. This means a higher volume yield per pound of pigment.
4. **Excellent Dispersion Characteristics**—as a result of careful production controls, ONCOR 23A pigment has a particularly uniform particle. This assures consistently good dispersion in both plastics and paints.

ONCOR 23A pigment is suggested for use in all halogenated plastic and paint compositions requiring flame resistance. It may be used with polyvinyl chloride, vinyl chloride copolymers, chlorinated paraffins, chlorinated rubber, chlorosulfonated polyethylene, chlorinated polyesters and the commercial fluoropolymers.

Additional information on the new ONCOR 23A pigment is provided in the National Lead Company Data Sheet just off the press. The handy coupon at the right will bring you a copy by return mail.



WITH ONCOR 23A **WITHOUT ONCOR 23A**

These two samples show typical flammability test results on vinyl film, following the procedure specified in ASTM D-1433-58. (See Item 1 in text.)

KC-6295

NLC

National Lead Company: General Offices, 111 Broadway, New York 6, N. Y. In Canada: 1401 McGill College Avenue, Montreal.

Gentlemen: Please send your new Data Sheet for ONCOR® 23A, antimony silico oxide pigment for flame retardance in halogenated plastics and paints.

Name _____ Title _____

Company _____

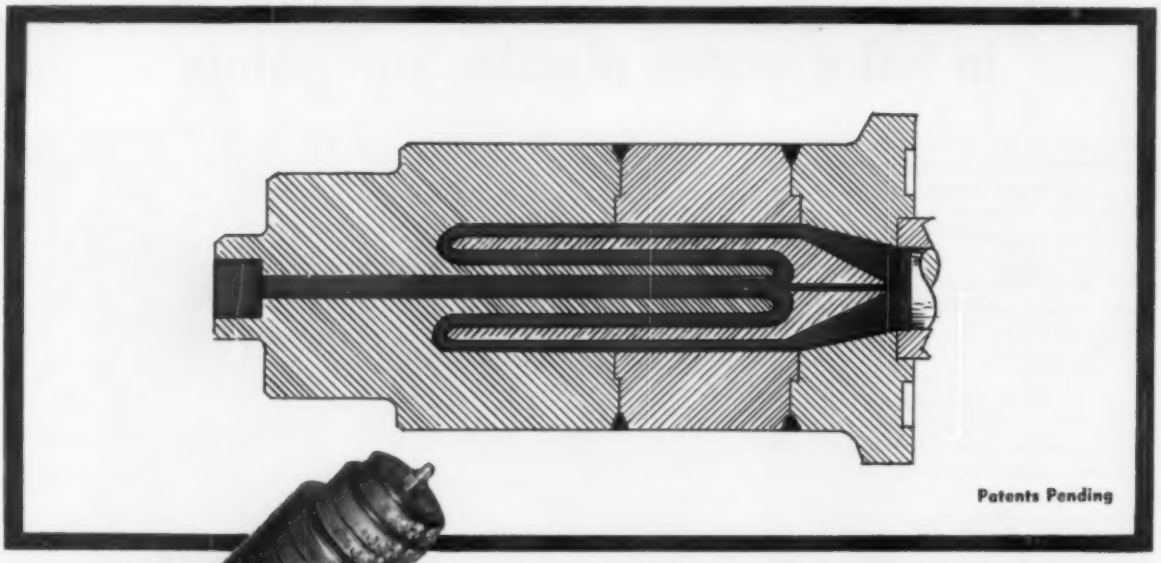
Address _____

City & Zone _____ State _____

23A an **oncor®** *Pigment... A Development of* **National Lead Company**

General Offices: 111 Broadway, New York 6, N.Y.

VRF Vented Reverse Flow Heaters



Patents Pending

Leading injection molders know— it's what happens INSIDE the heater that really counts!

Here's ultimate proof of IMS Leadership in heating cylinder design! The new exclusive VRF Degassing principle automatically overcomes many common molded-in defects. It's brought to you by the same cylinder engineers who pioneered the IMS Standard Uniform Design All-Welded Replacement Chamber in 1949. Note how the exclusive vent hole allows trapped, compressed gases to escape out of the melt area just prior to injection. This hot bleed-back speeds melting of cold granules, and often lowers pressure requirements by lubricating the spreader tip with soft plastic. You gain the advantages of precompression with no moving parts!

Cylinder corrosion on cellulosics is virtually eliminated by gas relief. Production time between clean-outs on Vinyl is greatly extended.

Pressure equalizing bleed-back gives automatic part weight control without a feed weigher.

VRF reduces burning because internal storage tube keeps material inventory away from heat source. Remember! It's what takes place INSIDE a heating cylinder that really counts!

IMS

SPECIAL PURPOSE REPLACEMENT
HEATING CYLINDERS FOR ALL
INJECTION MOLDING MACHINES.

INJECTION MOLDERS SUPPLY CO.
3514 LEE RD. CLEVELAND 20, OHIO

SPE JOURNAL NEWSLETTER

reading time
1 minute

Plastic Bleach Bottles

Blow molding continues to lead the packaging revolution. Blow molded, low-pressure polyethylene detergent containers moved in on the glass business, and it may happen again—this time packaging liquid bleach. Polyethylene and copolymers of ethylene and butylene are being used in experiments involving pigmented bleach bottles. Based on test results so far, at least one major bleach manufacturer is readying marketing plans involving blow-molded plastic bleach bottles.

Fire-Safe Storage of Foams

Ignition properties of plastic foams are no more hazardous than those of other common solids, such as lumber. This item and other information on fire-safe storage of foams is contained in a new Safety Guide, published by The Manufacturing Chemists' Association. The Guide points out that plastic foams tend to melt away from the source of heat thus reducing the likelihood of ignition. Flexible urethane foams will not self heat nor spontaneously ignite if proper catalyst systems are used.

Soundproof Laminate

Plastics move into the area of ceiling soundproofing materials. A New England manufacturer is marketing a product made by laminating a porous layer of cellulose film to each side of a core of rigid vinyl sheet. Patterns and colors can be printed on the exposed surface. Acoustical efficiency is achieved by perforating the vinyl sheet with small, evenly-spaced pores.

Bulk Handling

Foster Grant Co. has announced what may well be a future trend in handling resins. A bulk handling system for polystyrene, consisting of six 150,000-pound capacity silos to which the resin is blown by special cyclones from sealed Dry-flo rail cars. From there, the resin is piped to intermediate storage tanks inside the plant, and then to the molding and extrusion machines. Savings up to $0.04 a pound on the resin are said to be possible.

No Guesswork in Design

Methods for obtaining engineering and design data which can be applied to designing structural components with plastics, are reported on page 1231, this issue. The approaches described remove the guesswork from designing and enable engineers to relate short-time tests to long-term behavior.

new technical ideas • trends • industry news

NEED POLYETHYLENE?
NEED NYLON?
NEED POLYPROPYLENE?

Now ONE Truck Can Bring You All 3 Spencer Thermoplastics

STARTING right now, you can eliminate all the trouble and expense of ordering these three thermoplastic resins from different suppliers. With Spencer Chemical Company's complete family of "Poly-Eth" Polyethylene, Spencer Nylon and "Poly-Pro" Polypropylene resins, you can simply place one order, and the resins you need will arrive in *one shipment.*

And Spencer service is prompt! Once Spencer receives your order, you can expect overnight shipment and direct delivery—anywhere in the United States.

You get much more than convenience from ordering from Spencer. Spencer's complete family of thermoplastic resins all exhibit a broad and continuous range of desirable characteristics.

By ordering from Spencer, you also qualify for Spencer Chemical Company's fully integrated customer service:

Research and Development . . . discovers new and better materials for you!

Technical Service . . . helps solve processing and product problems for you!

Market Research and Development . . . develops new products and builds markets for you!

Product Improvement . . . designs specific formulations for you!

Add up the advantages for yourself: One order, one shipment for all three thermoplastics . . . overnight delivery . . . thermoplastics with a wide range of product and processing characteristics . . . and Spencer's fully integrated customer service!

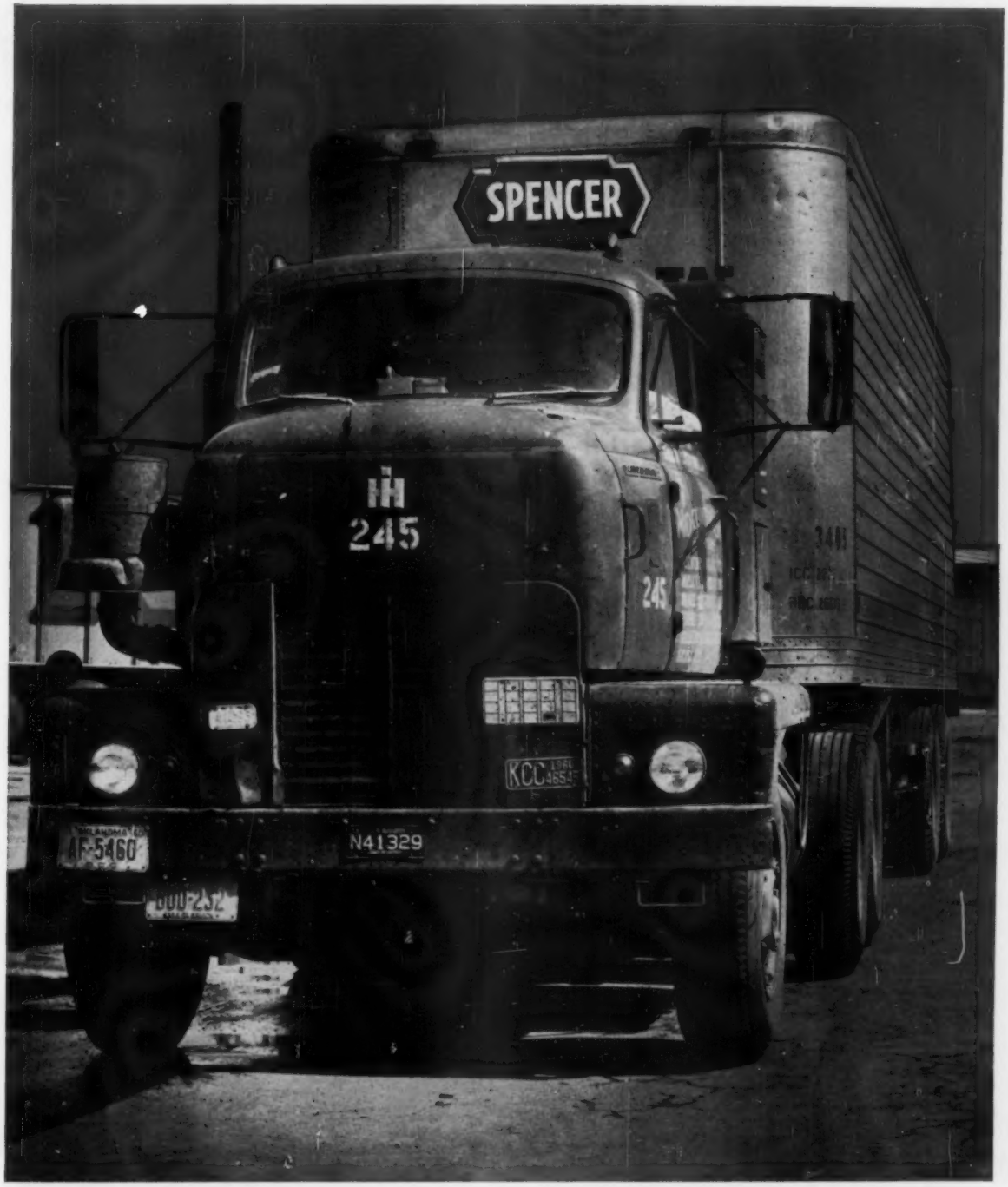
Call your Spencer sales office today.

KANSAS CITY . . . BAltimore 1-6600
NEW YORK . . . PLaza 2-1740
CHICAGO . . . RAndolph 6-3790
LOS ANGELES . . . OLeander 5-8540
ATLANTA . . . JAckson 4-0418
FORT WORTH . . . EDison 2-2782

Only SPENCER Offers You All 3 Of These Thermoplastics In ONE Truck!

SPENCER **Poly-Eth Polyethylene**

SPENCER CHEMICAL COMPANY



SPENCER **SPENCER NYLON**

SPENCER **POLY-PRO POLYPROPYLENE**

DWIGHT BLDG., KANSAS CITY 5, MISSOURI

"In 20 years, the REED 350 TCL–12/16 oz. is the most efficient molding machine I've ever seen. It has tremendous clamping pressure and fantastic speed. I'm getting a minimum of 25% more production on all my molds. Set-up is easy, and no matter how heavy the mold is, the movable die plate supports prevent tipping or sagging and misalignment of the halves."

ARMAND MARCUCILLI, *President*
Grace Plastic, Inc., New York

Monty Marcucilli is running a 16 oz. shot of high impact styrene on his new REED, casting an area over 200 sq. in. with .070 wall thickness. Call in your Reed-Prentice Sales Engineer and ask him to show you the improved performance you can get with the new 350 TCL—12/16 oz. REED.

REED-PRENTICE
division of
PACKAGE MACHINERY COMPANY
EAST LONGMEADOW, MASSACHUSETTS

BRANCH OFFICES: NEW YORK • CHICAGO • BUFFALO • CLEVELAND • DEARBORN • KANSAS CITY • LOS ANGELES

CELANESE
POLYMER COMPANY

Offers a Complete Service-in-Depth for Users of Plastic Materials

Celanese Polymer Company offers manufacturers, molders and product designers a comprehensive plastics service that includes assistance in application and design, plastics selection and product testing . . . laboratory and field service . . . and prompt deliveries from strategically located warehouse facilities.

Celanese Polymer Company is a Division of Celanese Corporation of America.

High, Medium and Low Density
POLYETHYLENE

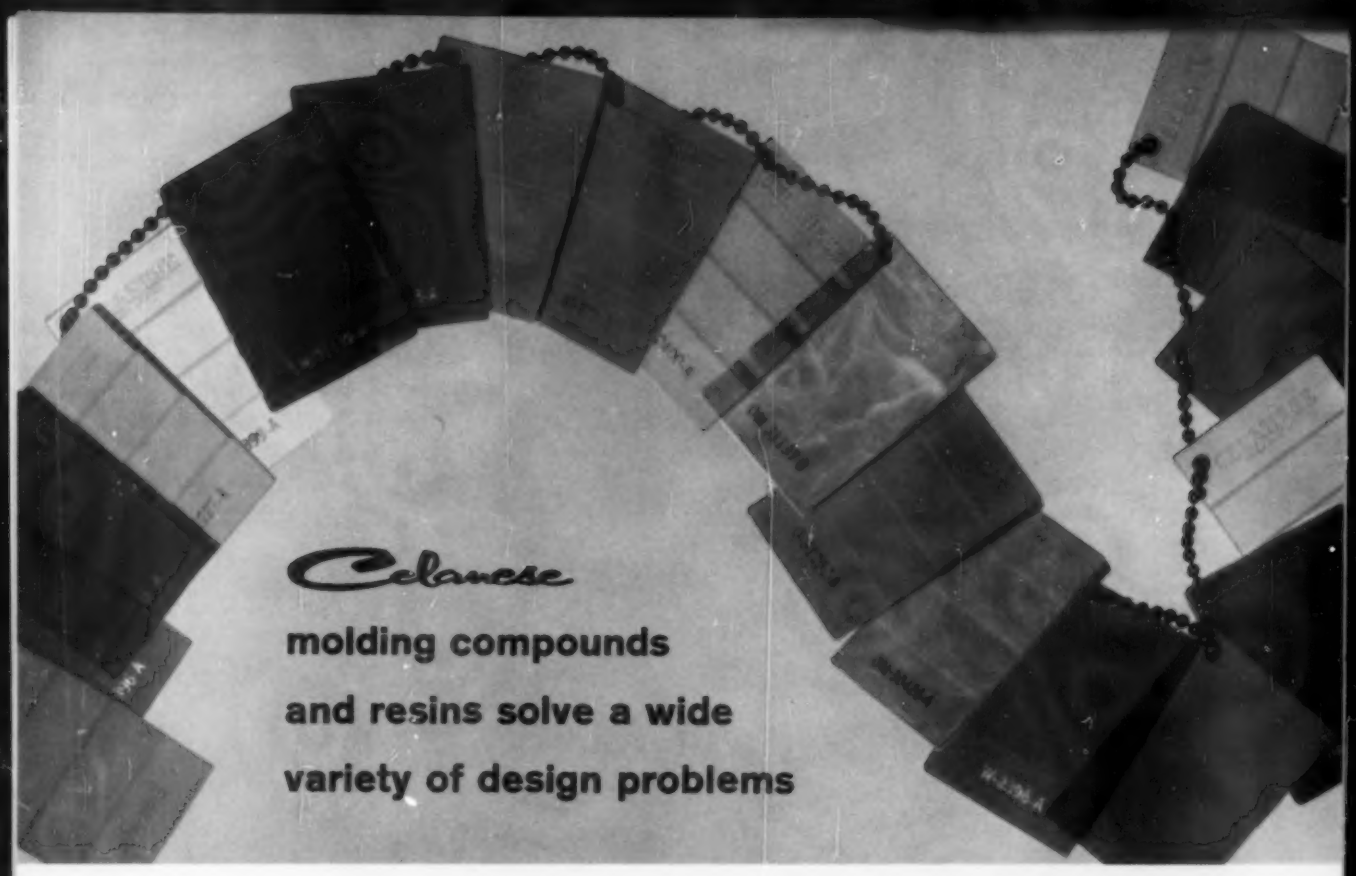
CELLULOSE PROPIONATE

CELLULOSE ACETATE

POLYESTER RESINS

Acetate, Propionate and Triacetate
CELLULOSE FLAKE

★ ★ ★
TECHNICAL SERVICE



Celanese molding compounds and resins solve a wide variety of design problems

FORTIFLEX . . . A Complete Range of Polyethylenes

Resins ranging from high to low density. There are four basic Fortiflex types: Series A, B, C, and D. Fortiflex A and B available in natural or scientifically color-matched to your specifications. Fortiflex C and D available in natural only. Applications: housewares, appliances, automotive and electrical parts, wire insulation, pipe, toys, containers, paper coating, film and sheet.

FORTICEL . . . Cellulose Propionate

Outstanding among thermoplastics for its excellent balance of properties, Forticel meets the demands of a number of automotive and appliance applications. Forticel has excellent dimensional stability, toughness, surface permanence and moldability, and is free of objectionable odor. Applications: automotive steering wheels and decorative trim, appliance and telephone housings, brush backs, dials, knobs and blow molded products.

ACETATE . . . Cellulose Acetate

Rugged, versatile, economical, Celanese Acetate is unequalled for its combination of toughness, clarity and price. It is available in a wide range of formulations and flows—in a limitless variety of scientifically matched colors. Applications: shoe heels, appliance housings, jewelry, tool handles, toys, sun glass frames, brush backs, houseware items and blow molded products.

POLYESTER RESINS

Here are the properties that speed production, cut down rejects. Celanese Polyester Resins offer fast cure, low drainage, better wet-out in hand lay-up. They are unequalled for saving time and labor on critical large area moldings. And they are outstanding for formulating and molding pre-mix and matched die parts. Applications: Boats, refrigerator doors, truck bodies, cooling tower grids, automotive and appliance parts, electronic housings, and decorative items.

CELLULOSIC FLAKES

Celanese offers cellulose acetate, cellulose triacetate and cellulose propionate flake in a variety of grades to basic industries such as plastics, sheet, film, fibers, protective coatings and adhesives. Specific applications include lacquer for paper, wire, and flashbulb coatings; film and sheeting for photography, graphic arts, and transparent packaging; molding powder for extrusion and injection molding of tool handles, tubing, and toys; and binders for color concentrates.

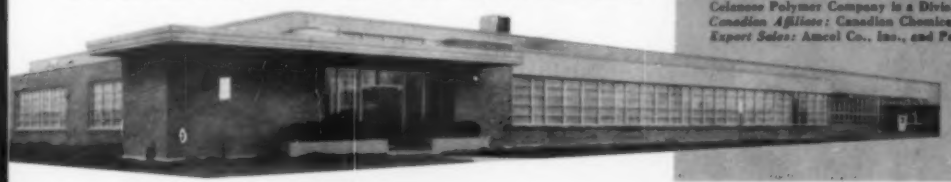
CELANESE TECHNICAL SERVICE

Celanese has the engineering staff to help you get the most out of plastic materials at any stage from design to finished product. This service includes: design consultation, assistance with mold design, material selection, equipment and its adaptation, pilot molding supervision and product testing.

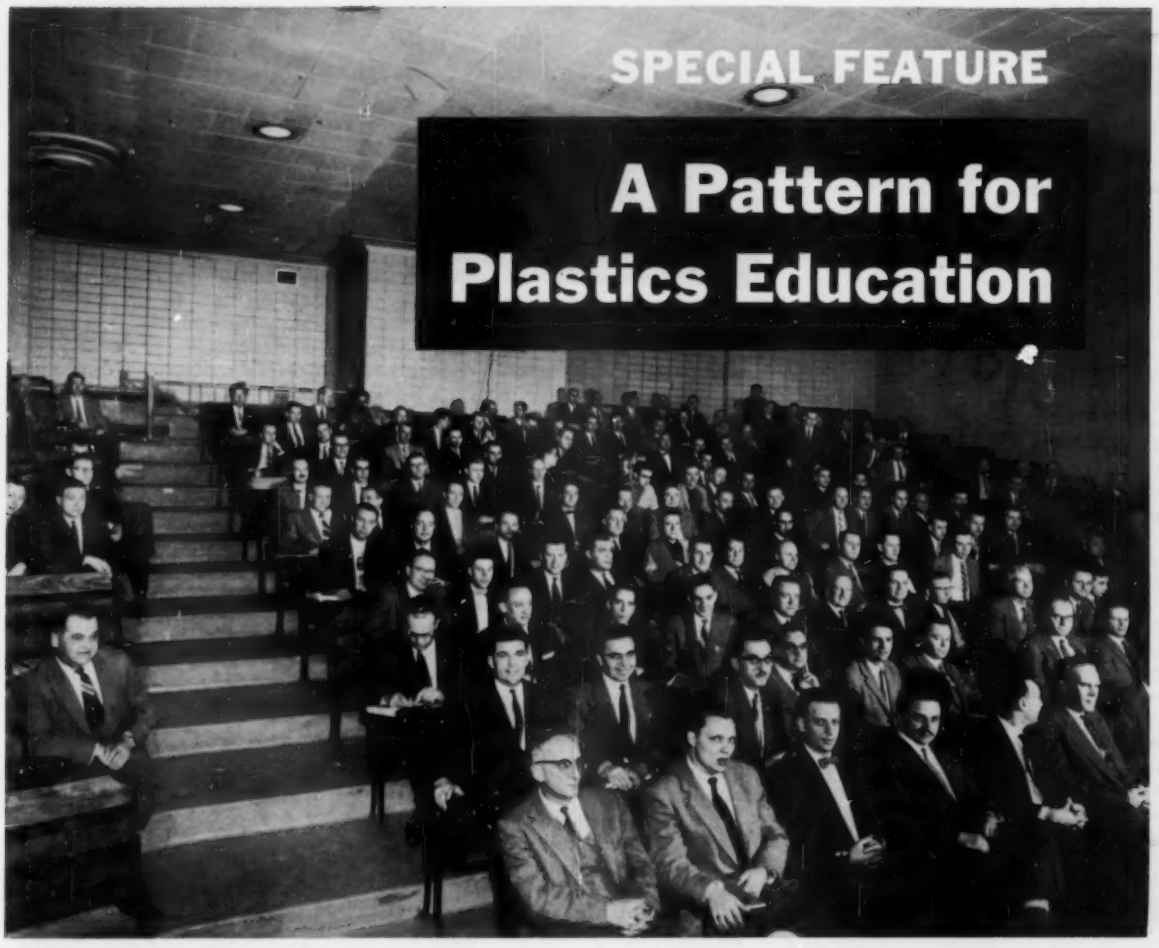
The Celanese Technical Service Laboratory is one of the finest of its type. It is complete with actual production equipment, color matching departments, and analytical and physical testing laboratories. For the right answers to problems of plastic application, or technical information on specific plastic materials, write: Celanese Polymer Company, Dept. GK-11, 744 Broad Street, Newark 2, New Jersey.

Celanese® Fortiflex® Forticel®

Celanese Polymer Company is a Division of Celanese Corporation of America.
Canadian Affiliate: Canadian Chemical Company Limited, Montreal, Toronto, Vancouver.
Export Sales: Amcel Co., Inc., and Pan Amcel Co., Inc., 180 Madison Ave., New York 16.



Celanese PLASTICS



SPECIAL FEATURE

A Pattern for Plastics Education

James E. Parkhill

Chairman, Ontario Section Education Committee
and Vice President, Barnett J. Danson & Associates Ltd.

One of the great essayists of the 18th century, Samuel Johnson, once said that "knowledge is of two kinds, we either know a thing ourselves or we know where we can find information upon it." Finding information upon plastics that is comprehensive and up to date, is not as simple as it may sound for to-days' engineer or businessman. There are comparatively few places where a person interested in plastics can go to study this field in its proper setting.

Ever since 1958, the Ontario Section of the SPE has been pursuing the somewhat elusive idea of a comprehensive study course on the whole field of plastics technology. There is probably no better way to discuss the topic of education in plastics than to describe in some detail the development, aims and accomplishments of this section with regard to the work being carried on at the University of Toronto. In the Toronto-Montreal area, there are hundreds of companies engaged in moulding plastics products or in manufacturing raw materials and equipment.

The Ontario Section took their first positive step towards a plastics study course during A. T. Orrs' tenure as President in 1958. This was in the form of an invitation to representatives of local technical schools and universities to participate in a panel discussion on the subject at a regular monthly section meeting. The discussion helped to consolidate the thinking of the members and enable us to take the second step toward our goal. The second step was a questionnaire which was mailed out to each of the members asking such questions as: Did the Industry feel there was a need for a plastics study course? What form should the course take? Should the level be theoretical or practical? Of the 150 questionnaires sent out, *100* were returned. Most respondents favoured an evening course and four out of five requested a course that would be general in its scope.

At a subsequent meeting of the University of Toronto with Dr. D. C. Williams, Director of the Division of the University extension, J. S. McIntyre, Associate Director and Professor W. G. McElhinney, Head of the Chemical Engineering Department and the writer, an agreement in principle was reached and reservation was made for a plastics course in the business and industry extension session which is conducted during the fall and winter months. In keeping with

the University policy of having a faculty member represented on courses sponsored by outside professional groups, Professor McElhinney was appointed by the University to assist the S. P. E. in carrying out the programme.

Aims of Course

In determining the direction the course should take, it was recognized that one of the main problems facing the Canadian Plastics Industry is the lack of trained people with a broad understanding of the total field of plastics technology. While there may not necessarily be any immediately obvious value, to say an injection moulder, to have a knowledge of thermosetting materials or reinforced plastics techniques, the long term values of wider knowledge cannot be denied.

Further support for this view was contained in the answers to the questionnaire. One person wrote: I would like to see a course that would embrace the entire plastics field. Another wrote: We are greatly handicapped by our lack of knowledge of other divisions of the industry. As a result, it was decided to attempt as broad a coverage as possible. The basic task accordingly, became one of preparing a course which would cover more than any one man could gain by working in one company. To achieve this aim has been a challenging task in view of the range of levels and experience among the participants. These included not only production men but also material suppliers, custom moulders, etc. The broad scope implied by the title of the course "Fundamentals and Technology of the Plastic Industry" obviously meant that many different technical disciplines would be involved. The lectures had to cover fully the present state of the industry, the physical and chemical properties of plastics, their production, manufacture and finishing and all the useful information which anyone working with plastics in any part of the industry would require.

Despite the emphasis on comprehensiveness, we were cognizant of the fact that the magnitude of this task could easily lead to a curriculum which would merely skim the surface without providing any real benefit to the students; it became, therefore, a matter of prime importance to see that the broad subject matter was balanced with corresponding depth of material in each area.

The final decision of the educational committee was to present the course in 35 lectures over a two year period. The first year should, it was felt, concentrate on the materials and should cover such aspects as their history, origin, raw material sources, physical, chemical and electrical properties, their limitations, and methods of their fabrication.

Ontario Section Education Committee in Session Left to right: James Wallace, Plastene (Canada) Ltd., Ken Blakeley, Chemical Oil & Resin Co., Bill Berry, Bakelite Co. Ltd., Maurice Chazottes, Progressive Plastics Magazine, Jim Parkhill, Barnett J. Danson & Associates Ltd., Ralph Bruton, Dow Chemical Co., Dick Buhr, Canadian Industries Ltd. Absent when this photograph was taken—Harold Shure, Naugatuck Chemicals, Chas. Seay, Eastman Chemical Ltd.

Organization

The purpose of the first years' coverage was to set up a suitable frame of reference for the second year of the course which would deal with specific equipment and techniques.

The makeup of the first year consisted of:

1. Introduction by the President of SPE in which an attempt was made to orientate the students with the industry and to familiarize them with the history of its various branches.

2. The second lecture entitled "Nomenclature of the Industry" was intended to generally acquaint the student with the technology that would be used by subsequent speakers, i.e. thermoplastics, thermosetting plastics, identification of families, definitions, etc.

3 and 4. The third and fourth lectures were designed to show the methods of determining physical properties of the materials and included an actual visit to the Labs at C.I.L.

5. The fifth lecture was entitled "Polymerization Theory," which attempted to explain the theoretical aspects of linkage and bondage that are fundamental to plastic materials.

6. Lecture No. 6 covered the thermosets, phenolics, ureas and melamines and was the only lecture dealing with compression moulded materials.

7. The next 8 lectures dealt with various thermoplastic materials including newer materials such as Delrin, polypropylene and Lexan.

8. Reinforced plastics were included under one heading and covered epoxies, polyesters, silicones and alkyds.

9. Foam plastics were similarly covered in one separate lecture and included vinyls, polyeurathanes, etc.

Near the conclusion of the course, two lectures were devoted to processing techniques for thermoplastics and thermosetting plastics. Both of these lectures were very general and were merely intended to prepare the student for more detailed study in the next years' course.

Speakers

While it was originally the intention of the Education Committee to act as a co-ordinating body and to serve in an advisory capacity to the University, it became apparent in the early stages that much more than this would be expected. The highly technical nature of nearly all of the lectures precluded the possibility of their being presented by anyone but an authority enlisted from the ranks of industry, and, 17 of the 18 lectures delivered the first year were by men with considerable experience in their respective fields. The choice of lecturers was based principally on reputation and every effort was made to secure leading figures not only from Canadian but also from the American plastics industry. Whenever possible, lecturers were given guidance in the aims and purposes of the course by members of the SPE Education Committee and by the University.

In general, all of the lectures were so well received (as demonstrated by a substantial increase in enrollment as the course progressed) that it is difficult to pick any outstanding performance. Special tribute is due to R. K. Buhr, who in addition to his duties on the education committee, delivered three of the lectures on the programme; and to Professor McElhinney, who delivered a key lecture on polymerization theory as well as acting as course director.

University of Toronto Course on Fundamentals and Technology of the Plastics Industry sponsored by Ontario Section of SPE

(second half of two-year course)

PROGRAMME

Section I

METHODS OF PROCESSING THERMOSETTING PLASTICS

October 4th

Opening Remarks: James E. Parkhill, Barnett J. Danson & Associates Ltd.

COMPRESSION MOULDING THERMOSETTING PLASTICS

Lecturer:
Roy Wilson, F. J. Stokes, Can. Ltd.

October 11th

FUNDAMENTALS OF THERMOSETTING MOULD DESIGN

Lecturer:
D. M. Buchanan and E. W. Vaill, Union Carbide Plastics, New York

October 18th

MOULDING THERMOSETTING PLASTICS

Lecturer:
H. A. Gadd, Plastics Section, Canadian General Electric

October 25th

FINISHING EQUIPMENT AND TECHNIQUES

Lecturer:
E. Burro, Durez Plastics, Hooker Electrochemical

November 1st

REINFORCED PLASTICS TECHNIQUES

Lecturer:
F. Harold Humphrey, Consultant, Markham, Ontario.

Section II

METHODS OF PROCESSING THERMO PLASTICS

November 8th

INJECTION MOULDING MACHINE ELEMENTS

Lecturer:
David J. Sloane, Lester Engineering Co., Cleveland 13, Ohio.

November 15th

FUNDAMENTALS OF THERMO PLASTIC MOULD DESIGN

Lecturer:
L. W. Meyer, Dow Chemical Co., Midland, Mich.

November 22nd

MOULDING THERMO PLASTICS

Lecturer:
M. Billings, Dow Chemical Co., Sarnia, Ontario.

November 29th

INJECTION MOULDING AUXILIARY EQUIPMENT

Lecturer:
A. R. Morse, Injection Moulders Supply, Cleveland, Ohio.

December 6th

FINISHING EQUIPMENT AND TECHNIQUES

Lecturer:
L. J. Shehan, Canadian General Electric Co., Ltd., Cobourg, Ontario.

Section III

EXTRUSION EQUIPMENT AND TECHNIQUES

January 10th

EXTRUSION MACHINE ELEMENTS

Lecturer:
George L. Bata, Carbide Chemicals, Montreal, Quebec.

January 17th

EXTRUSION MACHINE ELEMENTS

Lecturer:
George L. Bata, Carbide Chemicals, Montreal, Quebec.

January 24th

EXTRUSION TECHNIQUES THERMOPLASTIC MATERIALS

Lecturer:
George L. Bata, Carbide Chemicals, Montreal, Quebec.

Section IV

BLOW MOULDING AND VACUUM FORMING

February 7th

BLOW MOULDING EQUIPMENT AND TECHNIQUES

Lecturer:
Glenn A. Tanner, Auto Blow Co., Bridgeport, Conn.

February 14th

VACUUM FORMING EQUIPMENT AND TECHNIQUES

Lecturer:
W. Blamey, Auto Vac Co., Bridgeport, Conn.

February 21st

PANEL DISCUSSION
Presentation of Certificates.

As might be expected, the administration of the series was not all smooth sailing. For example, as the lectures progressed, it was found that some of the material was pitched at too high a level. Constant surveillance by the committee, however, permitted us to benefit from our early experiences, so that we were able to better advise our later speakers as to the desired content of their talks. Specifically, adverse comments were received when emphasis was placed on chemistry as opposed to application and properties. There was a definite preference by the majority of students for information of a practical nature which could be more directly related to their work.

Attendance

According to records kept, 237 people registered for the first year. Over 200 attended 85% of the lectures and thus qualified for a certificate of attendance to be presented at the end of the second year. Needless to say, *this represented a very high enrollment and an outstanding attendance record*. The significance of this can be better appreciated when it is realized that in many instances people came from moulding shops and processing plants in out-of-town locations. *Often this necessitated trips of over a hundred miles in an evening*. While the registration fee of $25.00 was usually borne by their companies, some of the students absorbed it themselves and in addition they paid their travelling expenses to and from the University.

While considerable success was achieved in attracting a number of persons within the industry, the number was not as high as originally hoped for. Approximately 60% of those enrolled were directly connected with the plastics industry; the rest were on the fringes of the industry and represented occupations such as design engineers, architects, engineering students, teachers, consultants, etc. The fact that there were fewer persons than expected from industry, undoubtedly is due to a number of factors. One may be that traditionally, educational programmes have been devoted primarily to meeting the needs of initiates rather than persons of experience.

Acknowledgments

This report has been written in the hope that it will assist other sections of the SPE who are considering sponsorship of an Extension course in plastics technology at the university level.

double your thinking capacity ?

A tall order. But not impossible. It's just what you have the potential of doing by reading scientific publications that report advanced research in your own field. Call it what you will, scientific insight, intuitive contemplation, or by any other name, but the possibility is always present that you may be able, in the solution of your own scientific problems, to apply some principle or idea gained from reading the written thoughts of others. One key sentence may double your thinking capacity on a given problem by the simple transfer of knowledge. If your field is polymer theory, science and engineering, you may be able to double your thinking capacity by reading SPE TRANSACTIONS, new publication of SPE. Beginning in January, 1961, and continuing quarterly thereafter, TRANSACTIONS will publish results of advanced research in the polymer field which will have far-reaching effects on the scientific and technological developments of tomorrow. Send in your subscription today.

MEMBER	
1 Year	$10.00
2 Years	18.00
3 Years	25.00
NON-MEMBERS	
U.S. & North American	
1 Year	$15.00
2 Years	28.00
3 Years	40.00
NON-MEMBERS	
Foreign	
1 Year	$25.00
2 Years	47.00
3 Years	67.00

Please enter my subscription to the new SPE TRANSACTIONS for the following period:

☐ 1 Year ☐ 2 Years ☐ 3 Years

Name .....

Street Address .....

City ..... Zone ..... State .....

Company .....

Title or position .....

☐ Member ☐ Check enclosed

☐ Non-Member ☐ Bill me later

mail coupon to SPE TRANSACTIONS 65 Prospect Street, Stamford, Conn.

U.S.I. POLYETHYLENE NEWS

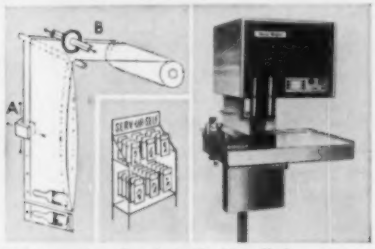
A series of advertisements for plastics and packaging executives by the makers of PETROTHENE polyethylene resins

Packaging Notes

"Rack-packaging" impulse buying items completely in one operation is now possible with this latest model, illustrated. *Packager-Sealer* which forms package around a product from open-end polyethylene film now comes equipped with two new accessories.

Using film with heat-sealed header, machine forms and seals package—while new *Register-Perforator* (A) punches ¼" holes in header at desired intervals, and new *Skip-Slit Perforator* (B) perforates along width of bag (top or bottom) for zip-off opening.

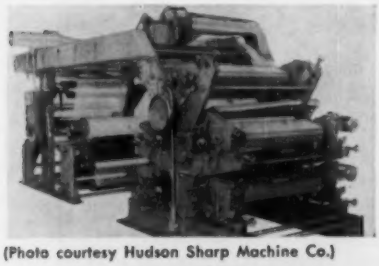
Machine with attachments saves one-half the cost of preformed bags, saves cost of grommets and grommeting operations, and reduces inventory of materials. Accessories also available separately.



(Photo courtesy See-Safe Machine Co.)

A compact, single-drum flexographic press, designed to meet the packaging industry's demands for close register color printing on narrow web widths of polyethylene, has recently been introduced. Reportedly, it is useful for shorter runs, incorporates principal features of larger flexographic presses. Cost is said to be comparable to that of many stack-type presses.

Standard equipment includes a 30" diameter single-impression cylinder with four color stations; new positive-locking device for color and plate cylinder frames. This device eliminates vibration, assures accurate adjustment and printing quality.



(Photo courtesy Hudson Sharp Machine Co.)

Polyethylene handles on 25-lb. multi-wall bags of granulated salt are being received favorably by consumers, according to a recent announcement. Injection-molded, the sturdy handles are simply sewn under the top tape during the ending operation. Bags need no special handling, as carriers lie back flat during filling, stacking, palletizing and shipping.

U.S.I.-International Constructing Offices and Laboratory in Baar, Switzerland

Will Help European Polyethylene Processors Expand Market, Improve Products

A new customer service laboratory and office building is currently being constructed at Sihlbruggstrasse, Baar, Switzerland, by U. S. Industrial Chemicals Company-International—officially incorporated October, 1959, as Sales and Development Company of National Distillers and Chemical Corporation (International) S.A. Temporary headquarters are at Kirchenstrasse 13, Zug, Switzerland. The new building in Baar, Canton of Zug, is scheduled to be ready for occupancy about July, 1961.

A model of the new laboratory and office being built by U.S.I.-International in Baar. The laboratory will be used to demonstrate best techniques for processing polyethylene.

Serves PETROTHENE Customers Abroad

The new facility will support the efforts of U.S.I.-International's representatives, through whom sales of PETROTHENE polyethylene resins will continue to be made. It will help them provide their customers with the close technical assistance which the polyethylene market demands. Experienced personnel will conduct research and evaluation studies to help improve products and develop new consumer markets. The United Kingdom, as well as European countries, will be served.

Well-Equipped Laboratory

The laboratory will be fully equipped with processing and test equipment designed to meet European standards and operating conditions. It will be used to demonstrate the best techniques for processing polyethylene into finished articles.

Polyethylene Used for Insulators in Nuclear Weapons Research

Two large polyethlene insulators, 18½ inches in diameter, have been made for use with a unique electrical switch in the discharge of heavy current loads from large condenser banks. Insulators and switch are reported to be part of research equipment used by nuclear physicists in the simulation and study of various aspects of nuclear weapons systems.

Polyethylene was chosen for its good insulating qualities, it is reported. Each insulator is said to be capable of withstanding voltages in the neighborhood of 100 kilovolts. The insulators were carefully milled to ensure design compatibility with the special two-million-ampere switch.

Milling polyethylene insulator for use with unique electrical switch in nuclear weapons research. (Photo courtesy Boeing Airplane Co.)

How to Build a Boat Shelter

To protect your boat against winter winds and snow, store it under polyethylene film. Lightweight, easy to handle, and inexpensive, it can be supported on a framework that's lighter and less expensive than the kind required by canvas coverings, according to the Canadian owner of a 37 ft. cruiser. He recommends building framework of bolted 2" x 2" lumber around the craft, covering it with 4 mil. black polyethylene, leaving a little slack. He makes vents in the roof, allows two feet between cover and ground.

U.S.I. Names New Vice-President

Paul J. La Marche has been made Vice-President of Production for U.S. Industrial Chemicals Co., Division of National Distillers and Chemical Corporation, it was announced by Robert E. Hulse, division General Manager and Executive Vice-President of the corporation.

Mr. La Marche joined the U.S.I. organization in 1949. Shortly afterward he became Manager of Sodium Sales. From 1951 to 1958 he was manager of the company's Ashtabula, Ohio, plants. He became Director of Production in October, 1958. Mr. La Marche is a graduate of Case Institute of Technology.

U.S.I.

Series V, No. 6

POLYETHYLENE PROCESSING TIPS

ANNEALING CHAMBER IMPROVES OPTICAL PROPERTIES OF POLYETHYLENE FILM

Clarity and gloss of blown polyethylene film are substantially improved by enclosing the blown tubing with an annealing chamber, or "chimney", located between the extruder die and air ring. (See schematic below.) The new technique has little significant effect on the strength characteristics of the film. It does, however, require closer control to maintain bubble stability.

The chimney, a development of U.S.I.'s Polymer Service Laboratory, can be made of inexpensive materials such as cardboard, glass or insulated metal. It can be constructed in two sections or hinged, to eliminate threading the "bubble" through the chamber.

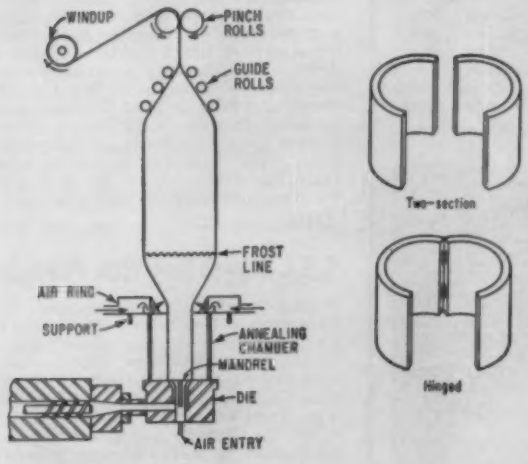
Although chamber diameter is not critical, best results are obtained with a chamber diameter 2" to 3" larger than the die diameter.

Importance of Retention Time

The degree of improvement in optical properties depends on retention time – the time it takes extruded film to travel from die lips to top of the chamber. This is a function of haul-off speed and chimney height.

A retention time of 2 seconds gives maximum optical improvement but requires a chamber height of 30" at haul-off speeds of 75 ft/min. This is not feasible from a production standpoint as serious blocking of warm film occurs and gauge is difficult to control.

With respect to production, a retention time of one second seems optimum. This gives significant optical improvement at more realistic chamber heights – 10"-14" – and haul-off rates – 50-70 ft/min.



Effect on Film Properties

Test results given in the accompanying table show that the annealing chamber improves the optical properties of film made from some polyethylene resins more than others. In both transmittance and gloss, low-density resins are improved more than higher-density resins; and higher-melt-index resins more than lower-melt-index resins.

An increase in blocking and reduction in slip may occur in some cases due to less time available for cooling. This can usually be corrected by increasing the distance between the die and the nip rolls, or by use of anti-block agents and higher slip formulations.

Technical Help and Data Available

U.S.I. engineers are continuing work on the annealing chamber study. They will be glad to consider your particular operation and help in adapting the method to your needs. You are also invited to write for a new paper describing the annealing chamber in greater detail. Address Technical Literature Department, U.S. Industrial Chemicals Co., 99 Park Ave., New York 16, N. Y.

How Annealing Affects Optical and Strength Properties of Film from PETROTHENE® Polyethylene Resins

PETROTHENE Resin	239-27 (5/MI; 0.929 density)		205 (3/MI; 0.924 density)		200-28 (3/MI; 0.916 density)		201 (5/MI; 0.916 density)	
Retention Time, Sec.	0	1	0	1	0	1	0	1
Haze, %	7.9	7.6	7.9	6.8	10.5	6.8	9.5	5.1
Gloss, %	10.2	11.8	10.9	12.3	7.5	9.3	6.9	10.4
Transmittance, %	68	72	54	61	38	57	39	70
Impact Strength Sand Bag, ft.	1	1.5	1	4	6	7.5	>9	>9
Dart Drop, g.	215	80	—	—	175	85	280	255
Elmen. Tear								
M.D.	175	140	165	60	65	40	60	45
T.D.	170	105	145	100	75	75	45	65

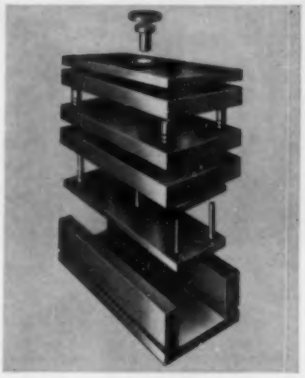
U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers and Chemical Corp.
99 Park Ave., New York 16, N. Y.
Branches in principal cities

3 WAY SAVINGS

WITH D-M-E STANDARD MOLD BASES

1 ADDED QUALITY

Exclusive design features provide extra-cost construction at standard prices! You get first-quality carbon or alloy steel, all surfaces ground flat and square, plus these features offered only by D-M-E: Patented tubular dowel construction; one-piece ejector housing; stop pins welded to ejector bar; sizes to 23¾" x 35½"; and the assurance that every D-M-E product is inspected *by the most modern methods and equipment.*



2 GREATER ECONOMY

Interchangeability lets you replace *any* component without special fitting or re-working! What's more, you can select from the widest range of Standard Mold Bases available anywhere—over 7,000 cataloged combinations.

3 FASTER SERVICE

Delivery from local stock means you get Standard Mold Bases, components and moldmakers' supplies when you need them —direct from D-M-E's fully-stocked local branches!

ARE YOU GETTING THE NEWS?

D-M-E's monthly publication is full of cost-saving ideas for designers, moldmakers and molders. Write on your letterhead—we'll place your name on the "NEWS" mailing list. No cost, no obligation.

DETROIT MOLD ENGINEERING COMPANY

DME

60-B

6686 E. McNichols Road—Detroit 12, Michigan—TWinbrook 1-1300

Contact your nearest branch for fast deliveries!

CHICAGO • HILLSIDE, N.J. • LOS ANGELES

D-M-E Corp., CLEVELAND, DAYTON; D-M-E of Canada, Inc., TORONTO

One-call service on Standard Components for Plastic Molding and Die-Casting

Injection and Compression Mold Bases • Injection Unit Molds • Cavity Retainer Sets • Mold Plates • Ejector and Core Pins • Ejector Housings • Leader Pins and Bushings • Sprue Bushings • Moldmakers' Tools and Supplies

custom-tailored...

Nothing can match the fit of a suit made to *your* measurements. And nothing can match the performance of an NRM Pacemaker extruder custom-built, *using standard interchangeable components*, to your exact production requirements. NRM's modular construction allows you to specify the right combination of drive horsepower, speed range, thrust capacity, screw type and heating-cooling systems for your particular operation. Find out how Pacemakers can meet today's — and can adapt to tomorrow's — production needs in your plant. Call, wire or write today. Ask for Bulletin PM-100.

2206-A

NRM

NATIONAL RUBBER MACHINERY COMPANY

General Offices: 47 WEST EXCHANGE ST. • AKRON 8, OHIO

A Staff Feature

SPEAKING OF EXTRUSION

Interest High in Maintenance Ideas for Extrusion Equipment

following are excerpts from just a few of the many letters received from readers of the maintenance article published by the SPE Journal in May 1960

•

We liked the Special Feature in your May SPE Journal. *L. J. Swift, General Manager, Industrial Plastics Corp.*

•

Please send as soon as possible a copy of extrusion maintenance article. *Leora E. Straka, Goodyear Tire and Rubber Co.*

•

The article was patterned along the lines that are useful to some of our affiliates. *P. J. Bonnell, Tech. Service Manager, U.S. Rubber International.*

•

Please send the writer two check-lists for extruder maintenance. *V. W. Carver, Waldron-Hartig Div., Midland-Ross Corp.*

•

Please send 10 copies. *Ray Frost, K-S-H Plastics, Inc.*

•

Please send 3 copies of the maintenance article. *H. Schumacker, Plastic Academy Products Corp.*

•

We would like to have 10 copies of the check-list. *Irving Abramowitz, Vice President-Manufacturing, Caron Products Corp.*

•

I would like to obtain 100 copies of your article Maintenance of Extrusion Equipment. *J. F. Pilaro, Customer Service Engineer, U.S. Industrial Chemicals Co.*

Technical Upgrading of Extrusion and Process Line Operators

Wide response to SPE Journal article describing maintenance of extrusion equipment points up need for exchange of information and ideas on equipment maintenance

The SPE Journal has published in the past several months a series of articles on maintenance and operation of extrusion and molding equipment (May page 489, June page 599, July page 682). The response for reprints and the expression of opinions of these articles by the plastics industry (see box, this page) has indicated a high level of interest.

Based on this interest, the editors of the SPE Journal feel that there may well be an area where the SPE Journal could be a national clearing house and focal point of information and interchange of knowledge at the operator level.

We are considering devoting a page in this Speaking of Extrusion Feature, either quarterly or three times a year, where you or your operator could write for advice on a mechanical maintenance or operational problem on any piece of processing equipment.

The daily responsibility for maintenance and care of your processing equipment rests with the operator. Providing a "point of communication" for his problem and the solutions of those problems should help him better able to carry out these responsibilities. The editorial staff of the Journal has the full cooperation of every equipment manufacturer, and will publish answers supplied by them to problems sent in by process engineers or operators. Likewise, the editors would welcome ideas and methods which have been used in successfully overcoming production problems. Such interchange of information can only benefit the entire industry.

It is to the industry's advantage to upgrade the technical knowledge level of the operators of this equipment. The editors would sincerely appreciate a card or letter indicating your thoughts on the value of such a feature.

—— ■ ——

edited by **Bruce H. Maddock,** *Union Carbide Plastics Co.*

You can get fast service on this broad line

ANYWHERE IN THE U.S.A.

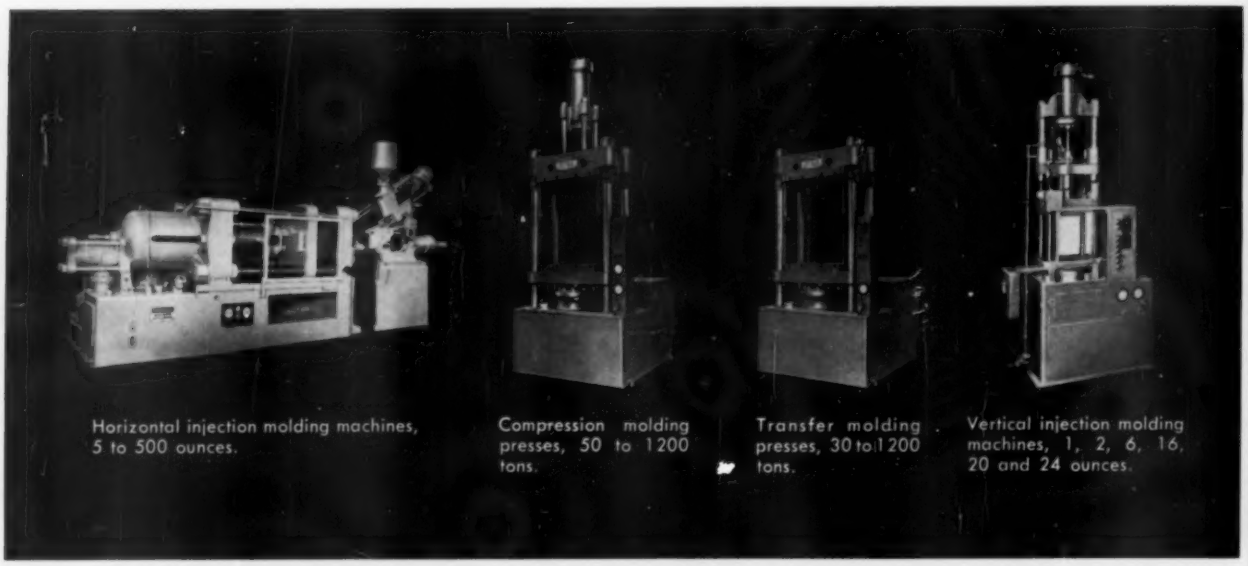
To provide even better service on your plastics molding machinery requirements, Watson-Stillman has added a number of new distributors to those already situated throughout the U.S.A. Any one of these distributors is ready to serve as your personal representative . . . assuring the fastest possible delivery with a minimum of lost time in order processing.

From the company's "Completeline" of equipment they can prescribe a machine that is tailored to the job. Because Watson-Stillman makes all types in a wide range of sizes, there is never any need to compromise. And remember: behind the machinery stands experience as old as the industry.

Need molding machinery? Contact the distributor nearest you. To start with, ask for bulletins covering the products in which you are interested.

FARREL-BIRMINGHAM COMPANY, INC.
WATSON-STILLMAN PRESS DIVISION
565 Blossom Road, Rochester 10, N. Y.
Plants: Ansonia and Derby, Conn., Buffalo and Rochester, N. Y.
European Office: Piazza della Republica 32, Milano, Italy
Represented in Canada by Barnett J. Danson, 1912 Avenue Road, Toronto, Ontario
Represented in Japan by The Gosho Company, Ltd. Machinery Department, Tokyo, Osaka, and Nagoya

FARREL
WATSON
STILLMAN



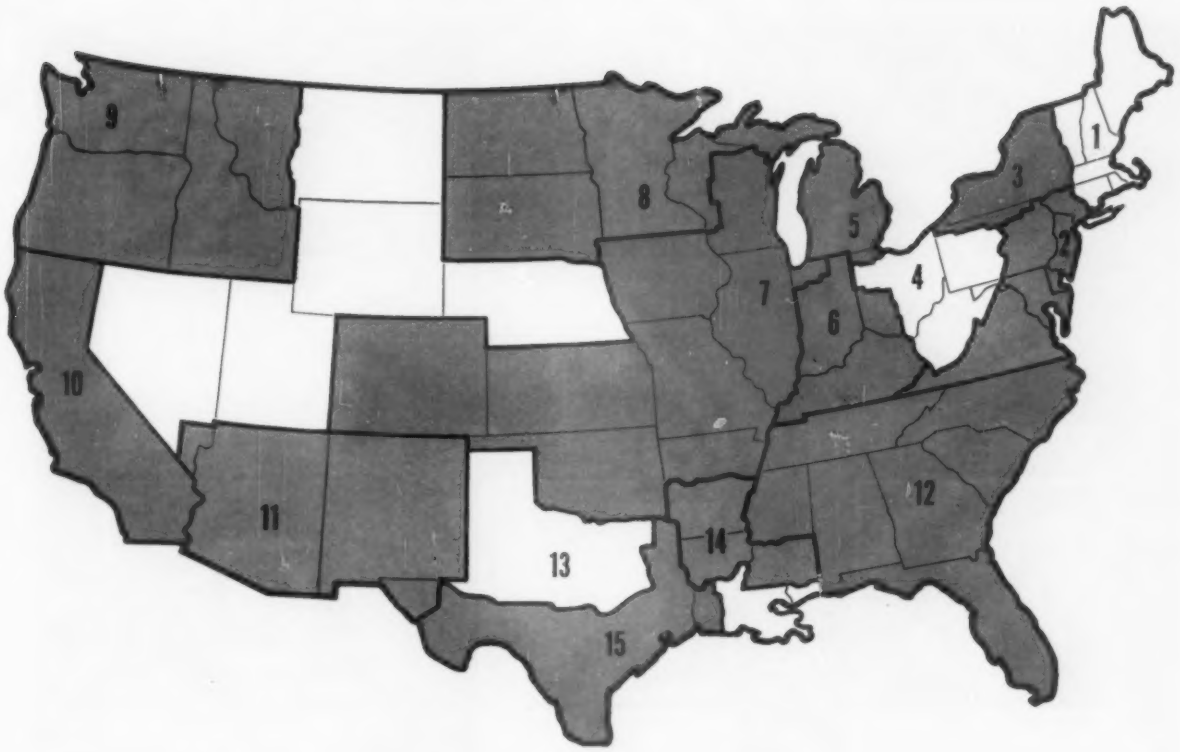
Horizontal injection molding machines, 5 to 500 ounces.

Compression molding presses, 50 to 1200 tons.

Transfer molding presses, 30 to 1200 tons.

Vertical injection molding machines, 1, 2, 6, 16, 20 and 24 ounces.

FARREL WATSON-STILLMAN MOLDING



General-purpose presses, 30 to 200 tons.

Laboratory presses, 30 to 100 tons.

MACHINERY

1 **HARROD-CARLSON MACHINERY, INC.**
846 Lexington Street
Waltham 54, Massachusetts
Telephone: TWinbrook 3-1001

2 **R. A. YORK**
3 Roberts Road
Plainfield, New Jersey
Telephone: PLainfield 5-0303

3 **FARREL-BIRMINGHAM COMPANY, INC.**
344 Vulcan Street
Buffalo 7, New York
Telephone: Bedford 3440

4 **FARREL-BIRMINGHAM COMPANY, INC.**
665 West Market Street
Akron 3, Ohio
Telephone: POrtage 2-8871

5 **BURLEIGH & STOCKER MACHINE TOOL CO.**
23675 Woodward Avenue
Pleasant Ridge, Michigan
Telephone: JOrdan 4-6555

6 **MILLHOLLAND & CONRAD, INC.**
6325 Guilford Avenue
Indianapolis 20, Indiana
Telephone: CLifford 5-4176

7 **FARREL-BIRMINGHAM COMPANY, INC.**
10725 South Western Avenue
Chicago 43, Illinois
Telephone: PRescott 9-3421

8 **THE SATTERLEE COMPANY**
2200 East Franklin Avenue
Minneapolis 4, Minnesota
Telephone: FEderal 3-5264

9 **D. A. OLSON COMPANY**
420 East 45th Street
Seattle 5, Washington
Telephone: MElrose 3-4133

10 **JAMES H. WOLCOTT MACHINERY CO.**
5819 Manton Avenue
Woodland Hills, California
Telephone: Diamond 6-6411

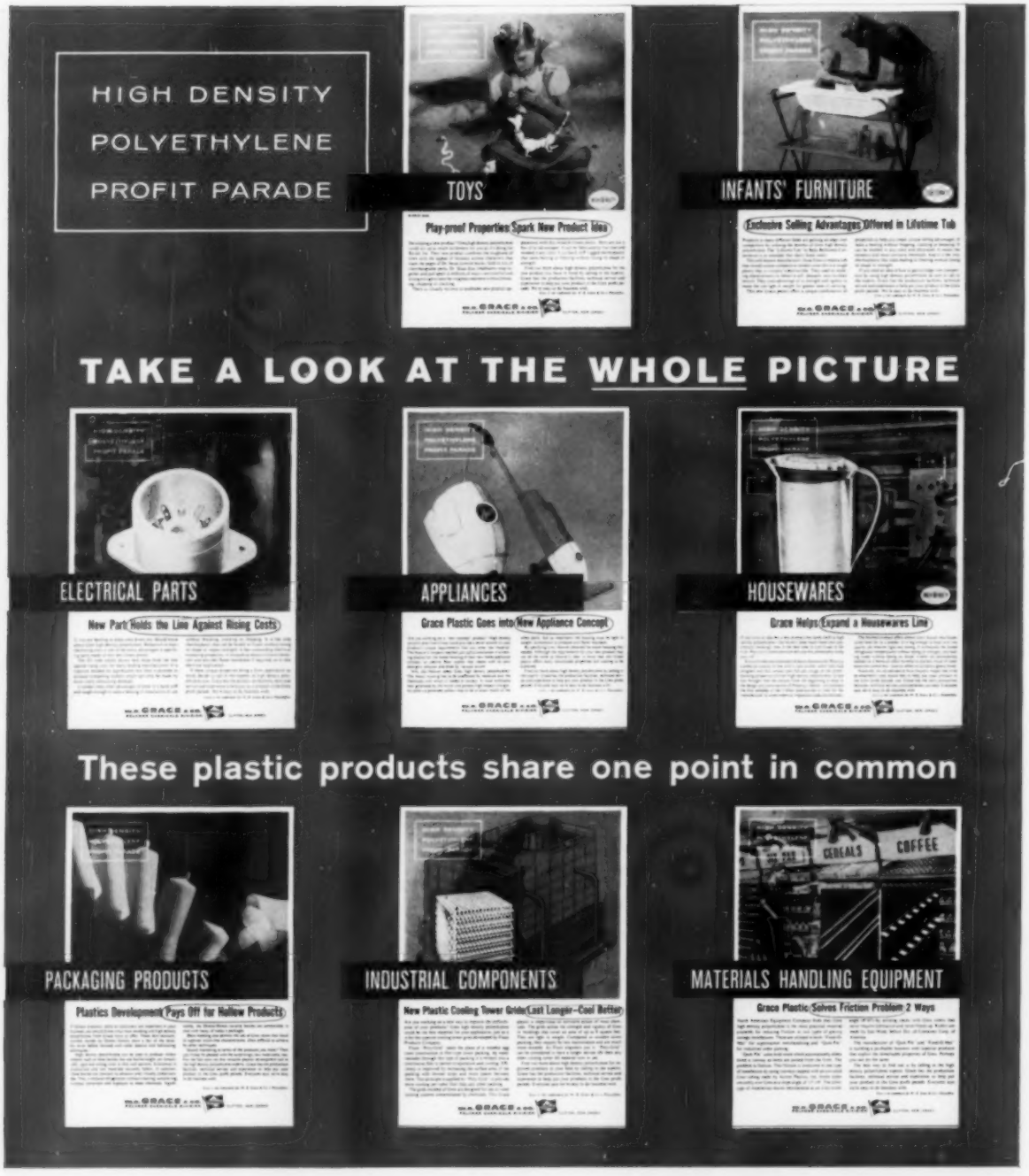
11 **SOUTHWEST MACHINE TOOL CORP.**
222 North 7th Avenue
P.O. Box 13626
Phoenix, Arizona
Telephone: AL 3-4197

12 **FARREL-BIRMINGHAM COMPANY, INC.**
710 Peachtree Street, N.E.
Atlanta 8, Georgia
Telephone: TRinity 6-1352

13 **NICHOLAS AND PARKS MACHINERY COMPANY**
2800 Commerce Street
P.O. Box 5729
Dallas 22, Texas
Telephone: RI 1-3246

14 **PEERLESS SUPPLY COMPANY, INC.**
701 Spring Street
P.O. Box 36
Shreveport, Louisiana
Telephone: 42-41451

15 **WESSENDORFF, NELMS & CO.**
5535 Harvey Wilson Drive
Houston 20, Texas
Telephone: WA 8-5151


HIGH DENSITY
POLYETHYLENE
PROFIT PARADE
TOYS
Play-proof Properties Spark New Product Idea
INFANTS' FURNITURE
Exclusive Selling Advantages Offered in Lifetime Tub
TAKE A LOOK AT THE WHOLE PICTURE
ELECTRICAL PARTS
New Part Holds the Line Against Rising Costs
APPLIANCES
Grace Plastic Goes into New Appliance Concept
HOUSEWARES
Grace Helps Expand a Housewares Line
These plastic products share one point in common
PACKAGING PRODUCTS
Plastics Development Pays Off for Hollow Products
INDUSTRIAL COMPONENTS
New Plastic Cooling Tower Grids Last Longer—Cost Better
CEREALS
COFFEE
MATERIALS HANDLING EQUIPMENT
Grace Plastic Solves Friction Problem 2 Ways

These products offer concrete evidence of manufacturers who have realized the profit-making opportunities to be found in high density polyethylene from W. R. Grace & Co. New products . . . better products . . . products that last longer . . . cost less to make . . . products with greater sales appeal . . . products that complete a product line—all can start with Grex High Density Polyethylene. If you have an application for high density polyethylene—or think you have—it will pay you to call Grace. *Grex is the trademark for W. R. Grace & Co.'s Polyolefins.*

W.R. GRACE & CO.
POLYMER CHEMICALS DIVISION
CLIFTON, NEW JERSEY

Thor L. Smith

Stanford Research Institute, Menlo Park, California

POLYMER SCIENCE

Ultimate Tensile Properties of Amorphous Polymers

The mechanical properties of a polymer, including its ultimate properties, depend on three factors: (1) the experimental conditions under which the properties are measured; (2) the physical state of the polymer; and (3) the structure of the polymer. Thus, before mechanical properties can be related to molecular structure and processes, the effects of these factors must be separated.

Depending on temperature and other experimental conditions, the properties of a polymer may be either glasslike, rubberlike, or liquidlike. For example (1), polyisobutylene of high molecular weight exhibits typical rubberlike properties at ambient temperature under most experimental conditions. But as either the temperature or the experimental time-scale is decreased, the properties became progressively more glasslike until eventually the material behaves like a typical organic glass (2). On the other hand, as either the temperature or the time scale is increased, the properties become progressively more liquidlike until the material behaves like a Newtonian liquid. (Crosslinked polymers do not exhibit liquidlike properties because the crosslinks, if stable, preclude permanent deformation or flow.)

Polymers in different physical states may have mechanical properties that either are inherently different or are different only under given experimental conditions. The latter behavior can be illustrated by considering two hypothetical amorphous polymers, one having a glass temperature T_g of $-80°$ and the other a T_g of 50°C. At ambient temperature, these polymers will have entirely different properties. But it is possible for the two polymers to have nearly identical properties at the same number of degrees above their glass temperatures, i.e., at equal values of $T-T_g$. On the other hand, crystalline and amorphous polymers have inherently different mechanical properties.

The mechanical properties of crystalline polymers are less amenable to being interrelated and to being related to molecular processes than are the properties of amorphous polymers at temperatures above T_g. A crystalline polymer has complex mechanical properties because the degree of crystallinity and the size, shape and possible orientation of the crystallites depend on the chemical nature, the temperature, the state of deformation, and the previous history of the polymer. Crystalline regions have entirely different mechanical properties than the surrounding amorphous phase. The properties of the amorphous phase will be either glassy or rubbery depending on whether or not the temperature is below or above T_g. Crystallization may even be produced by deforming a specimen of an otherwise amorphous material. Because of the complex characteristic of crystallization and crystalline polymers, this paper will be concerned primarily with polymers which remain amorphous under test conditions.

Although in an ultimate sense, the structure of a polymer determines its overall properties, certain structural parameters affect rather directly mechanical behavior. For uncrosslinked polymers, molecular weight, molecular weight distribution, and extent of chain branching affect the mechanical behavior, especially that observed at either high temperatures or under long experimental times. The properties of crosslinked polymers are affected by the number of effective chains, their molecular weight and distribution, the sol fraction, and other network parameters. Also, specific inter- or intra-chain attractive forces, such as those due to hydrogen bonds, can have a marked influence on mechanical behavior.

Experimental Methods

Mechanical properties are commonly studied (3) by measuring the time-dependent stress (or strain) produced by the application of a strain (or stress) which either remains constant, increases linearly, or varies sinusoidally during the test. These different experimental techniques yield different time-dependent quantities. When the deformations are small, the

mechanical response is linear viscoelastic, at least to a good approximation. Under those conditions, the quantities obtained from various tests can be interrelated (4, 5, 6) provided they cover the same range of the time scale. Because the transitions in mechanical behavior extend over many decades of logarithmic time, different experimental methods are commonly used to cover a wide range of the time scale. Thus, the different quantities measured must be converted into a single one before the results from the different tests can be combined. On the other hand, for non-linear viscoelastic behavior, no general methods are known for interconverting the results obtained by the use of different experimental techniques.

Although the mechanical properties of polymers are in general time-dependent, crosslinked polymers exhibit time-independent or equilibrium properties under certain experimental conditions. The mechanical response of such polymers becomes more nearly equilibrium as either the temperature or the time scale is increased. Thus, testing a specimen slowly at an elevated temperature usually gives an equilibrium or near-equilibrium stress-strain curve.

Ultimate properties of polymers are commonly measured in tension. Although many experimental methods can be used, common ones involve measurement of the stress (or strain) produced by applying a strain (or stress) which increases linearly with time until the specimen breaks. The stress and strain immediately prior to rupture are called the ultimate stress, or the stress-at-break*, and the ultimate strain. Usually the stress is defined as the applied load divided by the initial cross-sectional area of the specimen. Because the cross-sectional area decreases during a test, the stress ordinarily reported is usually considerably less than the true stress, the stress based on the cross-sectional area of the stressed specimen.

Ultimate tensile properties are also measured (7) by subjecting a specimen to a constant stress (usually a constant load) and observing the time-to-rupture and the ultimate strain. Likewise, a specimen can be subjected to a constant strain and the time-to-rupture and the stress-at-break measured (8).

For an amorphous polymer, ultimate properties measured at different constant strain rates and temperatures can often be interrelated, as discussed subsequently. Also, properties measured under different constant strains and temperatures can possibly be interrelated. However, methods for interrelating the data obtained from different experimental techniques do not exist. In fact few, if any, data of this type have been published, although Coleman (9) has reported and interrelated the tensile strengths of a fiber measured under constant loads and a constant loading rate.

In addition to the large effort required to obtain data under a variety of conditions, certain experimental difficulties associated with poor reproducibility are not infrequently encountered (10). For example, Kase (11) tested under identical conditions a large number of specimens from a single batch of an SBR rubber. He found the tensile strength varied widely, and thus he could characterize the strength of the material by only a most probable value or a distribution of values. To obtain such values under a variety of experimental conditions requires a prohibitive amount of work. In addition, it has been found (10, 12) that ultimate properties depend on the cross-sectional area and the length of the specimen tested; the smaller the cross-sectional area and the shorter its length, the greater is its strength.

Theoretical Considerations

Testing amorphous polymers at various strain rates and temperatures gives stress-strain curves like those shown schematically in *Figure 1*. The envelope ABC shows the dependence of the ultimate stress and strain on either strain rate or temperature, and OA represents the equilibrium stress-strain curve.

Strictly speaking, equilibrium conditions probably cannot exist along OA in the vicinity of point A. Excluding the rupture point, an equilibrium curve exists in the sense that measurements at rates below some value give curves that are independent, or nearly so, of rate. And measurements made at a fixed rate but at several temperatures give curves that are independent of temperature provided the temperatures are sufficiently high. Such behaviors are observed only if chemical degradation does not occur and a correction is made for the small increase in equilibrium stress produced by a temperature increase. Even though these criteria for equilibrium are met, the ultimate stress and strain depend somewhat on the testing rate and temperature. This

Figure 1. Schematic representation of the variation of stress-strain curves with strain rate and temperature. Envelope connects rupture points and the dotted lines illustrate stress relaxation and creep under different conditions (8)

statement is based on the generally-accepted hypothesis (13, 14, 9) that rupture, which requires breakage of primary valence bonds, is a process whose rate is affected by the existing stress. It is also based on the observation (15, 16, 17) that the ultimate stress and strain of amorphous elastomers do not attain constant values as the testing rate is decreased or the temperature is increased. Because rate and temperature affect the ultimate properties to a relatively minor degree under the conditions described, it can be assumed for present purposes that point A represents the "equilibrium" ultimate properties.

Suppose now that a specimen is stretched at the strain rate and temperature required to traverse curve OB and that the strain is held constant after point D is reached. At the constant strain, the stress relaxes, as indicated by the dotted vertical line,

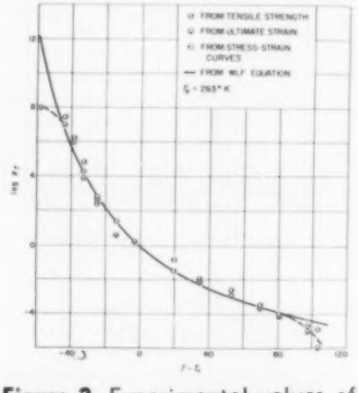


Figure 2. Experimental values of log a_T for an SBR rubber compared with the WLF equations. Points labeled "from stress-strain curves" discussed in reference 15.

* Because the tensile strength is usually defined as the maximum stress developed during certain types of tests, it seems desirable here to speak of the ultimate stress or the stress-at-break and to call this quantity the tensile strength only when it equals the maximum stress developed during a test.

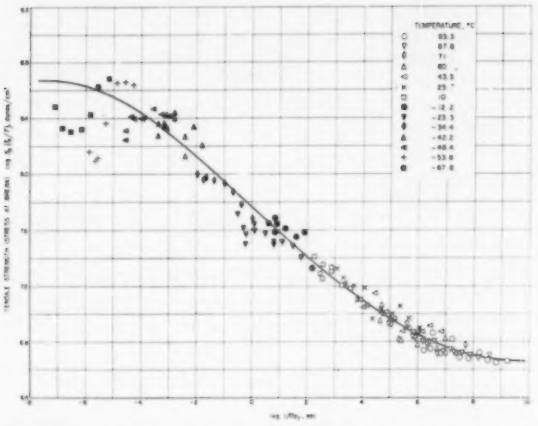


Figure 3. Variation of tensile strength of an SBR rubber with reduced strain rate Ra_T. ($T_s = 263°K.$) Values measured at various temperatures and rates (15)

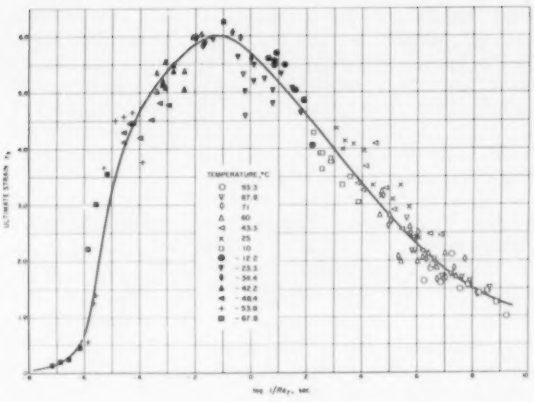


Figure 4. Variation of ultimate strain of an SBR rubber with reduced strain rate Ra_T ($T_s = 263°K.$) Values measured at various temperatures and rates (15)

until it reaches point E on the equilibrium stress-strain curve. On the other hand, if the stress is held constant after point D is reached, the strain increases, as indicated by the dotted horizontal line, until it reaches point F on the equilibrium stress-strain curve. Next suppose that curve OB is traversed until point G is reached and thereafter the strain is held constant. The stress relaxes, but because no equilibrium stress exists for the strain represented by point G, the specimen should eventually break. Likewise, if the stress is held constant after point G is reached, the strain increases, but because no equilibrium strain exists for the stress represented by point G, the specimen should eventually break.

These qualitative considerations show that the problem of understanding the ultimate tensile properties of amorphous elastomers can be subdivided into two parts. The first part deals with the questions of why the ultimate properties vary markedly with the experimental conditions and how the values obtained under different conditions are interrelated. The second part deals with relations between the structure of elastomers and their ultimate properties. This latter can best be studied by obtaining data under conditions such that the internal viscosity has little or no effect on the stress-strain behavior prior to specimen rupture.

Bueche (14) has treated theoretically the effect of temperature and time scale on the tensile strength measured under constant stress and various strain rates. His theory (14), which ignores the ultimate elongation, predicts that the tensile strength varies with temperature and time scale because of the effect of internal viscosity. Furthermore, the temperature dependence is predicted to be the same as for small-deformation viscoelastic quantities. To test the theory, Bueche (14) measured the tensile strength of polybutyl methacrylate under various loads at different temperatures, but he did not measure the tensile strength at various strain rates. The dependence of the tensile strength on load was in reasonable agreement with theory. However, Smith (15) measured the tensile strength of an SBR rubber at various strain rates and temperatures and found that the values did not agree with Bueche's theoretical curve.

Several theories have been proposed to explain the dependence of the tensile strength, measured in the absence of viscous effects, on network structure. These theories have been reviewed recently by F. Bueche (18). However, little work has been directed toward understanding the ultimate elongation and its relation to network structure, although one treatment has been proposed (19).

In the remaining portion of this paper, data are presented to illustrate the effect of experimental conditions, physical state, and polymer structure on the ultimate stress and elongation.

Factors Affecting Ultimate Properties

A. Experimental Conditions. A study (15) has been made to determine the effect of strain rate and temperature on the ultimate properties of an SBR rubber. Rubber rings were tested with an Instron tester at fourteen temperatures between −67.8 and 93.3°C and at a large number of rates between 9.48×10^{-3} to 9.48 min^{-1} at each temperature. The data at each temperature were plotted against log 1/R, where R is the strain rate. The resulting curves were then shifted along the log 1/R axis to effect superposition. The shift factors obtained by superposing both the tensile strength and ultimate elongation data are compared in *Figure 2* with the Williams, Landel, and Ferry (WLF) equation (20):

$$\log a_T = \frac{-8.86(T - T_s)}{101.6 + T - T_s}$$

where a_T is the shift factor, and T_s is a standard reference temperature which usually is 50°C above T_g.

The WLF equation, which gives the temperature dependence of the internal viscosity, has been used extensively to effect time-temperature superposition of small-deformation viscoelastic quantities. The constants 8.86 and 101.6 are near-universal, i.e., they are nearly the same for all amorphous polymers, although careful studies (21) have shown that they depend slightly on the nature of the polymer. The reference temperature in the WLF equation can be taken to be T_g. When this choice is made, the numerical constants 8.86 and 101.6 become 17.44 and 51.6, respectively. This form of the WLF equation predicts that different amorphous polymers are in corresponding temperature states at equal values of $T - T_g$.

Figure 2 shows that the values of log a_T obtained by superposing either the tensile strength or ultimate elongation data are in good agreement with the WLF equation, provided T_s is taken to be 263°K. This value of T_s was found by comparing graphically the experimental values of log a_T with those predicted by the WLF equation. The value found is quite ac-

curate because, if T_s equals T_g + 50°C, T_g should be −60°C, which value agrees closely with −63°C obtained directly from dilatometric measurements. The agreement with the WLF equation shows that the tensile strength and the ultimate elongation depend on temperature only because the internal viscosity changes. It also means that the ultimate properties depend on the strain rate because viscous resistance of network deformation increases with the rate.

All measured values of the ultimate properties of the SBR rubber are shown by the reduced plots in *Figures 3 and 4*. In these figures, the logarithm of the tensile strength and the ultimate strain are plotted against log $1/Ra_T$, where Ra_T is the reduced strain rate. These curves were constructed by the use of a_T values predicted by the WLF equation for temperatures between −53.8 and 71°C; at other temperatures, the values shown by the dotted line in *Figure 2* were used. It is seen that all experimental points lie reasonably close to the curves. These curves show that with increasing strain rate the tensile strength increases monotonically, except possibly at low temperatures or high strain rates where cold-drawing of specimens occurred, and the ultimate elongation increases from about 100% to 600% and then drops sharply toward zero.

From the reduced plots and the temperature dependence of a_T, the ultimate properties can be predicted over a wide range of strain rate at temperatures above T_g. At the reference temperature, which is 263°K for the curves shown, a_T equals unity. Thus, the curves show directly the ultimate properties over a wide range of strain rate at 263°K. At other temperatures, the appropriate values of a_T must be used to convert the reduced strain rate into the strain rate R_T which produces the same effect at temperature T as the strain rate R does at temperature T_s.

Implicit in the use of the reduced curves for predicting ultimate properties are the assumptions that heating effects are negligible and that the stress distribution in a specimen is uniform at all times during a test. Heating of a specimen is most pronounced at low temperatures and high strain rates. At exceedingly high strain rates, the resulting stress distribution will not be uniform because of wave-propagation effects. These complicating factors need to be considered when reduced plots are used to predict the ultimate tensile properties at high rates.

The time-to-break (t_b) at a strain rate R equals γ_b/R, where γ_b is the ultimate strain. Thus, the ultimate properties, shown in *Figures 3 and 4*, can be plotted against log t_b, as in *Figure 5*. The curves in *Figure 5* appear to be approaching asymptotes of zero slope at long times although, as discussed previously, such asymptotes probably do not exist.

Because ultimate properties apparently had not been measured under conditions of constant strain, a study of this type was made recently (8) to determine (a) whether or not a specimen maintained at constant strain will in fact show delayed rupture, (b) whether rupture is controlled solely by viscous relaxation, and (c) certain relations between time-to-break under conditions of constant strain and of constant strain rate.

The SBR rubber studied had, unfortunately, a molecular weight between crosslinks of nearly 16,000, almost double that of the SBR studied previously at various strain rates (15). Specimens were subjected to constant strains, and the resulting stresses were measured either until rupture occurred or for periods up to about seven days. Such tests were made at eight temperatures between 1.7 and 60°C. The experimental techniques and the results are discussed in detail elsewhere (8).

Typical results are presented in *Figure 6* which shows relaxation data obtained on eight specimens maintained at elongations between 350 and 525% and at 1.7°C. The solid circles indicate rupture, and the dotted line represents the stress-at-break as a function of time. All data obtained at 1.7, 7.2, 12.8, and 18.3°C are shown in *Figures 7 and 8* where the ultimate elongation and the logarithm of stress-at-break are plotted against log t_b. (The quantity A is arbitrary and is used only to separate the curves for clarity.) Similar data were also obtained at four temperatures between 29.4 and 60°C. The data, which for the most part appear to be reasonably reproducible, demonstrate conclusively that delayed rupture of a specimen maintained at a constant elongation can occur.

Both the stress-at-break and the ultimate elongation data at the eight temperatures were shifted along the log t_b axis to effect superposition. Because some of the data could not be superposed well, precise values could not be obtained for certain of the shift factors a_T. Although the values obtained are consistent with the WLF equation, they are not sufficiently precise and do not extend over a sufficiently wide temperature range to prove that the rupture is controlled solely by viscous relaxation. But the results, when considered along with those obtained at constant strain rates (15), strongly suggest that the rupture is controlled by viscous relaxation, except possibly at the highest temperatures.

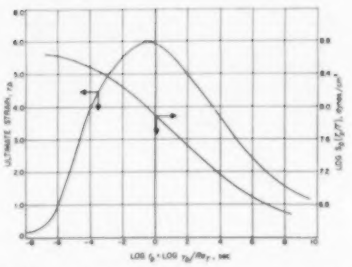


Figure 5. Ultimate property data from Figs. 3 and 4 plotted against time-to-break reduced to −10°C (8)

Ultimate properties of the SBR rubber were also measured at several strain rates and various temperatures. Such data were needed so that a comparison could be made of the time-to-break under conditions of constant strain and of constant strain rate. The results show that for a given value of either the ultimate elongation or the stress-at-break, the time-to-break under a constant strain is less than under a constant strain rate. Because relatively few data were obtained under constant strain rate, no quantitative conclusions were reached about the relative effects of the two types of experimental conditions on the time-to-break.

B. Physical State. The WLF equation predicts that polymers are in corresponding temperature states at equal values of $T-T_g$. Thus, certain polymers which have the same number of effective network chains per unit volume (ν_e), i.e., have the same equilibrium modulus, but have different glass temperatures might be expected to have the same ultimate properties in corresponding states. In any event, ultimate properties of different polymers should be compared at equal values of $T-T_g$ before any speculations are made regarding possible relations between their structure and ultimate properties.

Four polyurethane elastomers (22) have been prepared from polyoxypropylene glycol 2025, 1, 1, 1-trimethylolpropane, and either hexamethylene-1, 6-diisocyanate, toluene-2, 4-diisocyanate, m-phenylene diisocyanate, or naphthalene-1, 5-diisocyanate. These elastomers had similar values of ν_e (calculated from their equilibrium moduli) but had T_g values ranging from −67.5 to −17°C. They

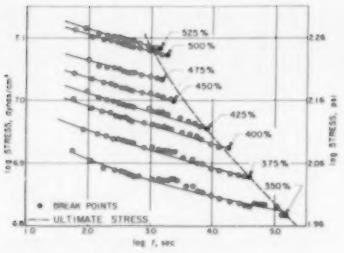


Figure 6. Stress relaxation of an SBR rubber at 1.7°C under elongations from 350 to 525%. Solid points indicate rupture. (SBR different than for Figs. 2-5) [8]

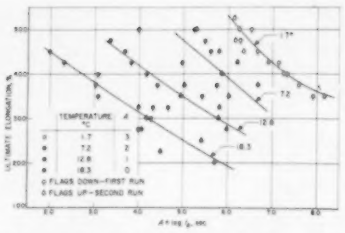


Figure 7. Variation of the ultimate elongation with time-to-break for an SBR rubber under constant elongations. (Values of A are arbitrary. SBR different than for Figs. 2-5). [8]

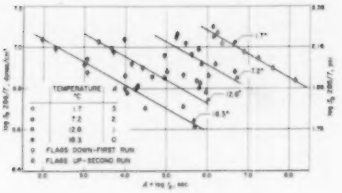


Figure 8. Dependence of stress-at a break reduced to 286°K (S_b 286/T) on time-to-break for an SBR rubber under the constant elongations shown in Fig. 7. (Values of A are arbitrary. SBR different than for Figs. 2-5) [8]

were tested at a strain rate of about 3 min^{-1} and at various temperatures between −40 and 70°C. *Figure 9* shows that their ultimate properties are markedly different. But when the properties are plotted against $T-T_g$, as in *Figure 10*, single curves are obtained. Within the experimental uncertainty, it is thus concluded that these elastomers have the same ultimate properties in corresponding states.

Other examples (16, 22, 23) have been given which show that certain elastomers have the same ultimate properties in corresponding temperature states. As expected, it has also been found that the ultimate properties of different elastomers, which have similar values of ν_e, have markedly different ultimate properties even in corresponding states. Such differences can potentially be related to different inter- or intra-chain attractive forces and to different arrangements the network chains.

C. Polymer Structure. Obtaining an improved understanding of relations between ultimate properties and polymer structure is now hampered by the lack of extensive data of the proper type. Much existing data have been measured under poorly defined conditions, e.g., it is often not known whether or not the data were influenced by the internal viscosity. To prevent such uncertainties, ultimate properties should be measured at a series of temperatures in the range $80° < T-T_g < 140°C$ to assure that data are obtained in the absence of viscous effects and that the data on different elastomers can be compared in corresponding temperature states.

Ultimate properties are affected pronouncedly by the irregularities and defects intrinsic to all networks. Such factors affect the ultimate properties because the chains in a network (even those orientated in one direction) are not subjected to the same load when a specimen is stretched. Bueche (18) has estimated that the tensile strength of a perfect network would be about 50,000 psi. This estimate indicates that network imperfections are of major importance because observed tensile strengths are lower by factors of, say 10-500.

Some information has been obtained recently on the effect of ν_e on the ultimate properties of some polyurethane elastomers (22). The elastomers were prepared from toluene-2, 4-diisocyanate and mixtures of polyoxypropylene glycol 2025 (PPG) and dipropylene glycol (DPG). They were crosslinked by six polyols, and the concentration of each crosslinker was varied over a wide range. The PPG/DPG ratio was adjusted to give all elastomers a urethane group concentration (U) of 1.57 moles/kg; this gave elastomers having approximately the same T_g (−48°C). Values of ν_e were calculated from measured values of the equilibrium, or near-equilibrium, modulus. The ultimate properties were measured at several temperatures at a strain rate of 3 min^{-1}, and the results are shown in *Figures 11 and 12*.

The data in *Figures 11 and 12* show that the ultimate properties are independent of the type of crosslinker, within experimental error. For these elastomers, the tensile strength does not pass through a maximum with increasing ν_e, as has been reported by Taylor and Darin (24) for unfilled SBR vulcanizates and by Bueche (25) for filled SBR vulcanizates. But the results obtained by Epstein and Smith (19) on SBR vulcanizates strongly indicate that the maximum reported by Taylor and Darin is spurious and was caused by a viscous effect, i.e., the stress-strain curves prior to rupture of certain vulcanizates were not equilibrium ones. When data were obtained (19) under more-nearly equilibrium conditions, the maximum in the plot of tensile strength against ν_e disappeared.

The tensile strength (S_b) and ultimate elongation ($100\ \gamma_b$) data at the

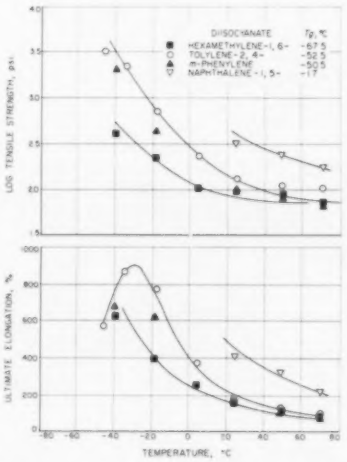


Figure 9. Temperature dependence of the tensile strength and the ultimate elongation of four polyurethane elastomers. Data measured at a strain rate of 3 min^{-1}

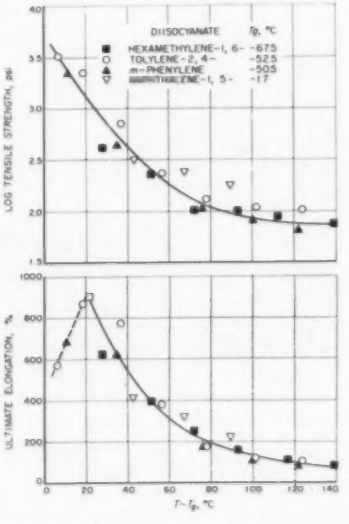


Figure 10. Data shown in Figure 9 plotted against $T-T_g$ (22)

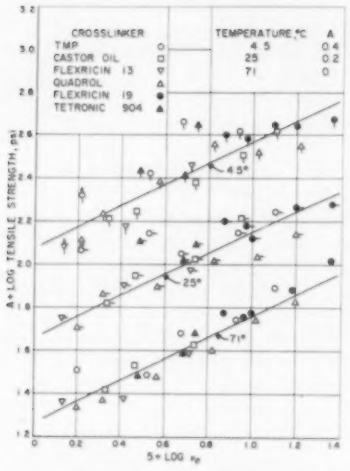


Figure 11. Dependence of the tensile strength on the number of effective chains per unit volume. Data measured at a strain rate of 3 min^{-1}. Elastomers are polyurethanes containing different crosslinkers and crosslinker concentrations (Values of A are arbitrary.) [22]

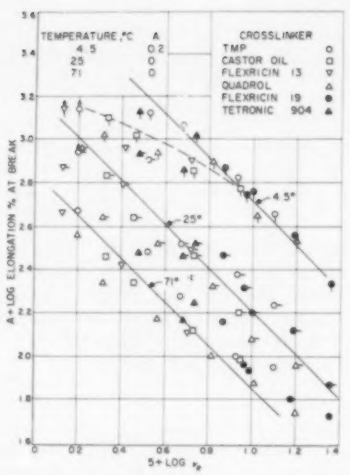


Figure 12. Dependence of the ultimate elongation on the number of effective chains per unit volume. Elastomers and test conditions same as described under Fig. 11. (Values of A are arbitrary.) [22]

three temperatures shown in *Figures 11 and 12* fit the equations $S_b = K_1(T)\nu_e^{1/2}$ and $100\ \gamma_b = K_2(T)\nu_e^{-1}$, where $K_1(T)$ and $K_2(T)$ are functions only of temperature. These temperature functions equal the tensile strength and ultimate elongation, respectively, of a hypothetical elastomer for which ν_e equals unity. Although $K_1(T)$ and $K_2(T)$ are independent of ν_e, at least over a certain range, these functions may depend on structure or chemical nature.

The dependence of $K_1(T)$ and $K_2(T)$ on structure can be illustrated by considering some data obtained on polyurethane elastomers (16) which were similar to those described above except they had a U = 2.30 moles/kg ($T_g = -34°C$) instead of 1.70 moles/kg ($T_g = -48°C$). For the elastomers having a U = 2.30, values of $K_2(T)$ were evaluated at various temperatures. However, values of $K_1(T)$ could not be obtained because the tensile strength was independent of ν_e over the range investigated; this range was narrower than for the other type of elastomers being considered.

Figure 13 shows plots of log $K_2(T)$ vs $T-T_g$ for both types of elastomers and a plot of log $K_1(T)$ vs $T-T_g$ for the elastomers having a U = 1.57. For the elastomers having a U = 1.57, values of $K_1(T)$ and $K_2(T)$ at the three lowest temperatures apply over a more restricted range of ν_e than shown in *Figures 11 and 12*. *Figure 13* shows that $K_2(T)$ depends on U. This dependence indicates that

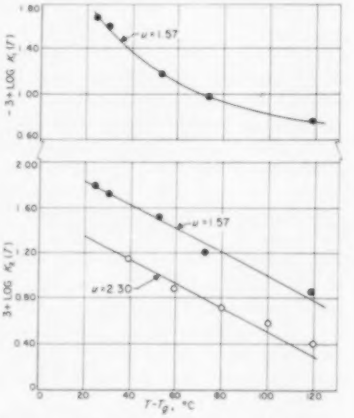


Figure 13. Variation of log $K_1(T)$ and log $K_2(T)$ with $T-T_g$ for polyurethane elastomers having a U = 2.30 ($T_g = -34°C$) and a U = 1.57 ($T_g = -48°C$). [22]

certain specific differences exist in the structure of the two types of elastomers or in the characteristics of their chains.

Literature References

1. Marvin, R. S., *Proceedings of the Second International Congress on Rheology*, V. G. W. Harrison, ed., Academic Press Inc., New York (1954), p. 156.
2. Buchdahl, R., *Rheology*, Vol. 2, chapt. 4, F. R. Eirich, ed., Academic Press Inc., New York (1958).
3. Ferry, J. D., *Rheology*, Vol. 2, chapt. 11, F. R. Eirich, ed., Academic Press Inc., New York (1958).
4. Gross, B., *J. Appl. Phys. 18*, 212 (1947); *19*, 257 (1948).
5. Gross, B. and Pelzer, H., *J. Appl. Phys. 22*, 1305 (1951).
6. Smith, T. L., *Trans. Soc. Rheology 2*, 131 (1958).
7. Staverman, A. J. and Schwarzl, F., *Die Physik der Hochpolymeren*, Vol. IV, chapt. 2, H. A. Stewart, ed., Springer, Berlin (1956). Also, Haward, R. N., *Strength of Plastics and Glasses*, Interscience, New York (1949). These references contain a few typical examples.
8. Smith, T. L. and Stedry, P. J., *J. Appl. Phys. 31*, (in publication) (1960).
9. Coleman, B. D., *J. Polymer Sci. 20*, 447 (1956).
10. Schwarzl, F. and Staverman, A. J., *Die Physik der Hochpolymeren*, Vol. IV, chapt. 3, H. A. Stuart, ed., Springer, Berlin (1956).
11. Kase, S., *J. Polymer Sci. 11*, 425 (1953); *14*, 497 and 579 (1954).
12. Higuchi, T., Leeper, H. M. and Davis, D. S., *Anal. Chem. 20*, 1029 (1948).
13. Bueche, A. M., *J. Polymer Sci. 19*, 275 (1956).
14. Bueche, F., *J. Appl. Phys. 26*, 1133 (1955).
15. Smith, T. L., *J. Polymer Sci. 32*, 99 (1958).
16. Smith, T. L. and Magnusson, A. B., *J. Polymer Sci. 42*, 391 (1960).
17. Formandi, G., Ecker, R. and Heidemann, W., *Proceedings International Rubber Conference*, p. 177, American Chemical Society publication (1959).
18. Bueche, F., *Rubber Chem. and Tech. 32*, 1269 (1959).
19. Epstein, I. M. and Smith, R. P., *Trans. Soc. Rheology 2*, 219 (1958).
20. Williams, M. L., Landel, R. F. and Ferry, J. D., *J. Am. Chem. Soc. 77*, 3701 (1955).
21. Ferry, J. D. and Landel, R. F., *Kolloid-Zeitschrift 148*, 1 (1956).
22. Smith, T. L. and Magnusson, A. B., *J. Appl. Polymer Sci.*, accepted for publication.
23. Borders, A. M. and Juve, R. D., *Ind. Eng. Chem. 38*, 1066 (1946); *Rubber Chem. and Tech. 20*, 515 (1947).
24. Taylor, G. R. and Darin, S. R., *J. Polymer Sci. 17*, 511 (1955).
25. Bueche, F., *J. Polymer Sci. 33*, 259 (1958).

Edited by **Dr. Irvin Wolock**
U.S. Naval Research Laboratory

RCI POLYLITE Plastic Concrete Forms Cut Building Costs!

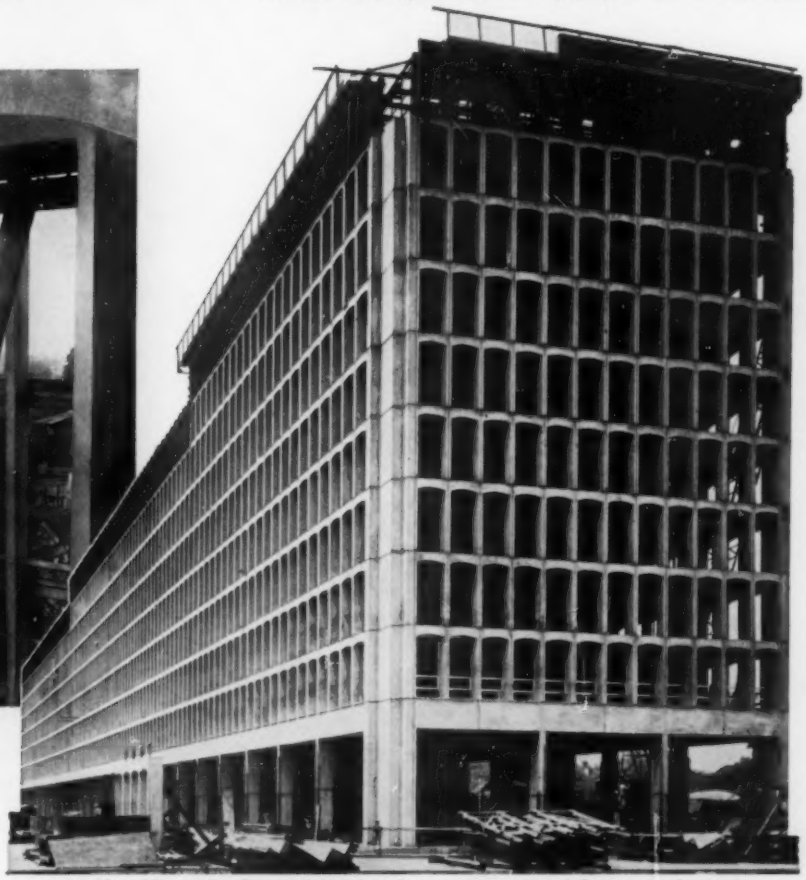
• "Reinforced plastic concrete forms made with RCI's POLYLITE polyester resin were responsible for cutting form costs by one-third in this Webb and Knapp apartment project," states Myron Austin, design engineer for Engineered Concrete Form Corporation, Chicago.

Al Schreck, carpenter superintendent for James McHugh Construction Co., Chicago, found these important advantages in reinforced plastic forms:

- They can be adapted to virtually any shape.
- They have greater strength to withstand the impact stresses of cement pours; flexural strength is about 30,000 psi.
- Light in weight, about half that of a lumber form, they can be handled and erected more economically.
- Highly resistant to abrasion, they can be used over and over again.
- Low expansion/contraction properties of reinforced plastic forms, when exposed to heat and cold, provide a high degree of dimensional accuracy in the cured concrete.
- The smooth plastic surface of the forms provide the trowelled-like finish of a skilled concrete artisan, without extra cost.

This is only one example of how plastics are improving on old techniques. If you have an application which might be simplified or improved by the use of reinforced polyester, it will pay you to call on RCI.

Part of the Webb and Knapp apartment project in Chicago which contains 4,500 arched windows poured in POLYLITE plastic forms; and close-up of one of the POLYLITE forms. With proper handling, forms can be used 50 to 100 times.



Webb and Knapp, Developer — I. M. Pei, Architects — James McHugh Construction Company, Concrete Subcontractor — Engineered Concrete Form Corporation, Form Manufacturer

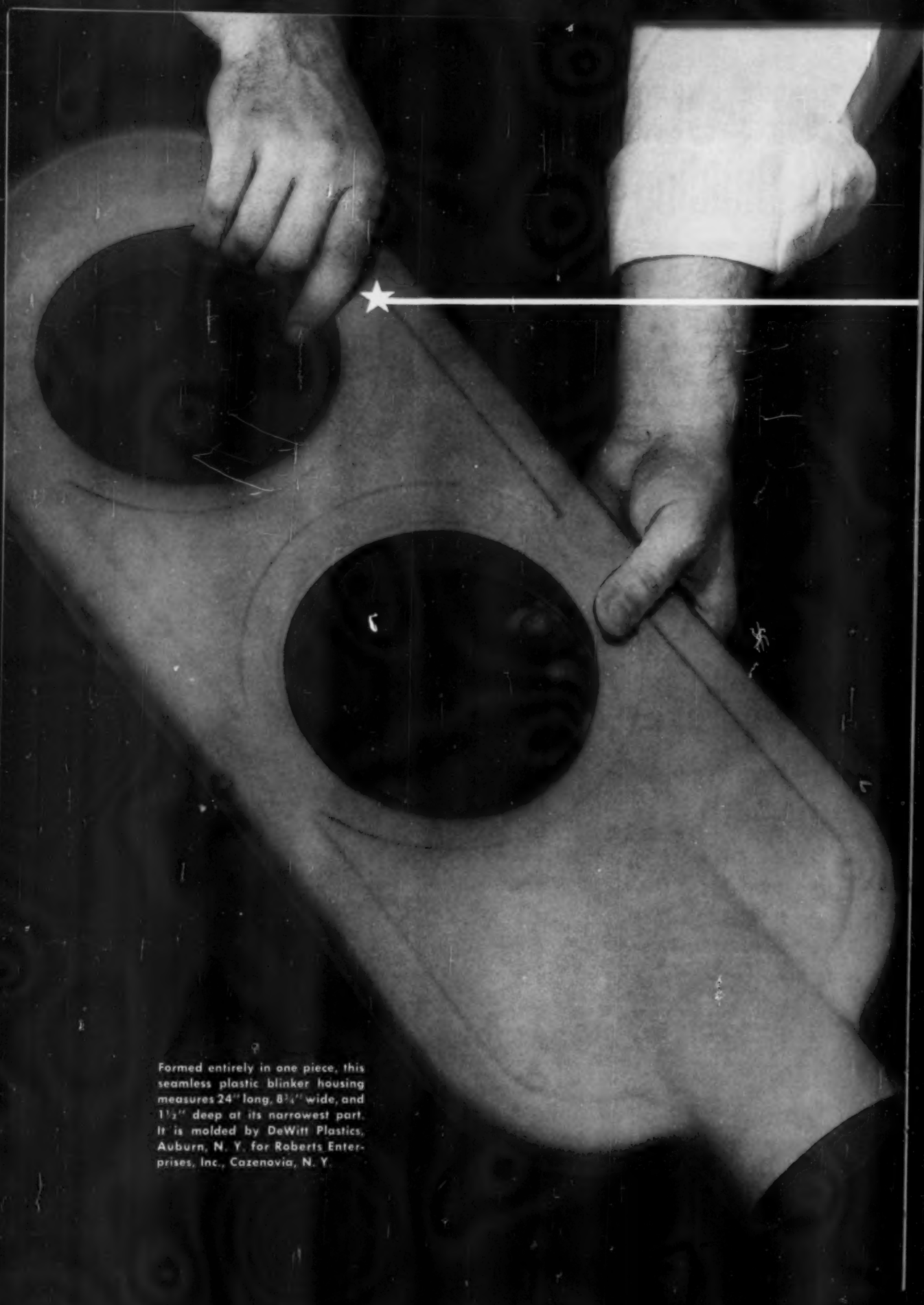
Creative Chemistry ... Your Partner in Progress

RCI

REICHHOLD

Synthetic Resins • Chemical Colors • Industrial Adhesives • Phenol • Hydrochloric Acid
Formaldehyde • Phthalic Anhydride • Maleic Anhydride • Ortho-Phenylphenol • Sodium Sulfite
Pentaerythritol • Pentachlorophenol • Sodium Pentachlorophenate • Sulfuric Acid • Methanol

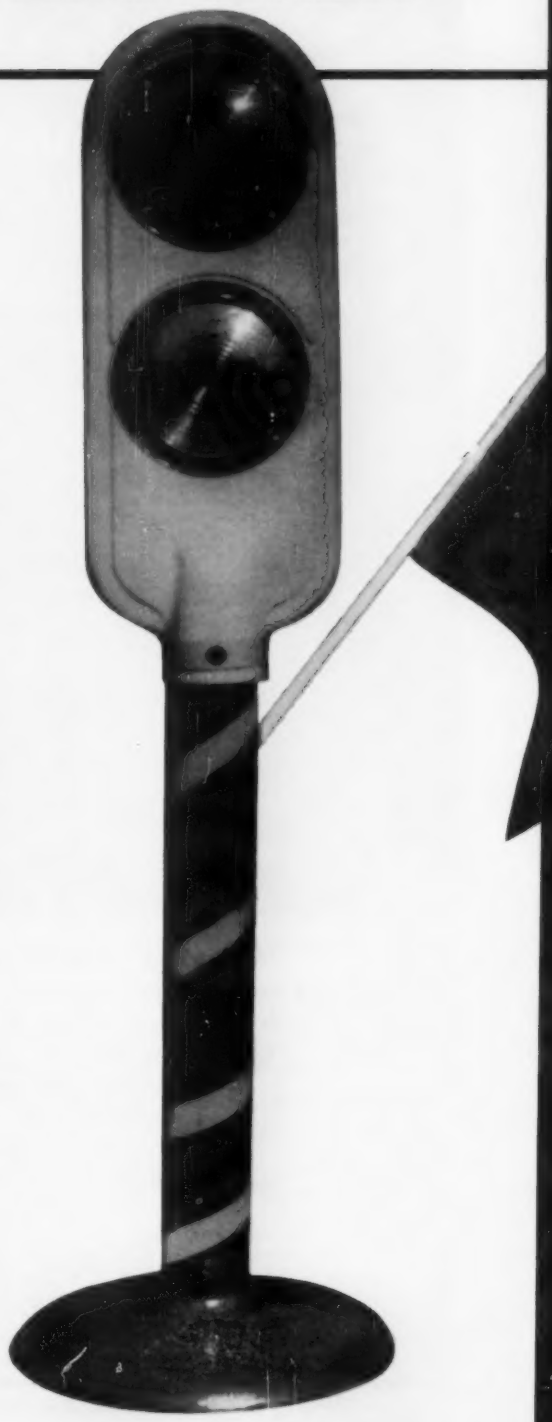
REICHHOLD CHEMICALS, INC., RCI BUILDING, WHITE PLAINS, N.Y.



Formed entirely in one piece, this seamless plastic blinker housing measures 24" long, 8¾" wide, and 1½" deep at its narrowest part. It is molded by DeWitt Plastics, Auburn, N. Y. for Roberts Enterprises, Inc., Cazenovia, N. Y.

STOP...LOOK WHAT'S NEW

IN BLOW-MOLDED POLYETHYLENE!



This flashing road barricade is a beacon of safety for motorists. Its yellow plastic blinker housing shows something else, too. Good design. Selection of the *right* process, the *right* material. Only blow molding could make this part in one piece. And BAKELITE Brand high-density polyethylene provides the durability to stand long, tough outdoor use.

The background of UNION CARBIDE in blow molding dates from the earliest application of polyethylene to squeeze bottles. At our laboratories in Bound Brook, N. J., a battery of all major types of blow molding machines reproduces practically every set of production line conditions encountered in the process. As a result, BAKELITE Brand polyethylenes are engineered for performance in machine and product alike.

You can get every type of polyethylene for blow molding from Union Carbide Plastics Company. BAKELITE Brand polyethylenes range from low to high density materials, including .95 to .96 density types. Nowhere else in the industry is the list so complete. You get the benefits of one-source selection.

For information on how UNION CARBIDE materials and experience in blow molding can help you develop a successful product, write Dept. FR-132, Union Carbide Plastics Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. *In Canada:* Union Carbide Canada Limited, Toronto 12.

UNION CARBIDE

BAKELITE and UNION CARBIDE are registered trade marks of Union Carbide Corporation.

IMPCO'S NEW SECOND-STAGE INJECTOR

The Second Stage Injector was designed to increase the effective operation of any Impco Injection Molding Machine now in service. It is also now available as standard equipment on new Impco machines. Its use gives you:

- Raw material savings
- Increased capacity
- Reduced molding pressures
- Increased mold area
- Simplified nylon molding
- Fewer rejects

Ask for Bulletin P-127 for more information.

IMPCO®

IMPROVED MACHINERY INC.
NASHUA, NEW HAMPSHIRE

MANUFACTURERS OF IMPCO PLASTIC MOLDING MACHINES

Harry Raech, Jr.

Norair Div., Northrop Corp.

REINFORCED PLASTICS

A Working Bibliography for the Field of Reinforced Plastics

Review abstracts of selected bibliography covers RP from adhesives and latex techniques to basic fiber properties and premix molding

REINFORCED PLASTICS • • • Bibliography

Plastics Engineering Handbook—The Society of the Plastics Industry, Inc.

Reinhold Publishing Corp., 1960, 6½ by 9¼, 565 pages, $15.00.

Adjudged Prerequisites: Blueprint reading, high-school chemistry.

This is a general reference book sponsored by The Society of the Plastics Industry for use as a general reference book by those in the periphery of the plastics industry. Because of the intended use of this text, it is particularly broad, and has as its general sections materials and processes, design, finishing and assembly, testing, and SPI Standards.

Because of this very broadness, the book is of particular value to the neophyte in the plastics field. It is unlikely that any other single volume of equivalent size can better serve the dual role of being a broad introduction to the field, and "pocketbook" of plastics engineering. In this latter aspect it comes closest of all plastics books to being an "Engineer's Handbook" in the field of plastics. Excellent tabulations are given of the properties of classes of plastics, and the design of molded articles is treated in great detail, including tabulations of design tolerances of parts.

Editor's Note

Mr. Raech compiled the reviews published on these pages working as a member of the Reinforced Plastics Professional Activity Committee, Western Section, Mr. S. S. Oleesky, Chairman. Mr. George Lubin is Chairman of the RP Professional Activity Group.

REINFORCED PLASTICS • • • Bibliography

Polymer Processes—C. E. Schildknecht

Interscience Publishers, Inc., 6¼ by 9¼, 914 pages, $19.50.

Adjudged Prerequisites: Organic and physical chemistry.

The subtitle of this book—"Chemical Technology of Plastics, Resins, Rubbers, Adhesives and Fibers, Edited by C. E. Schildknecht" probably describes the work much better than the major title. It is a work comprised of the contributions of an international aggregation of specialists, and is on a basic resin-formulation level. Little discussion is given to molding, fabrication or application. Among the basic areas covered are: bulk, suspension, free radical, emulsion, solution and ionic polymerization; polyesters, epoxies, polysulphides and formaldehyde derivatives. The last portion of the book covers process subjects including adhesives, paste and latex techniques and reinforced plastics techniques. The section on reinforced plastics is particularly good, more basic information on the applied chemistry of general-purpose types of laminates being provided in seventy pages than is commonly given between two covers in books on that particular subject.

REINFORCED PLASTICS • • • Bibliography

Modern Materials—H. H. Hausner

Academic Press, Inc., 1958, 6¼ by 9¼, 402 pages, $12.50.

Adjudged Prerequisites: High school chemistry and physics.

While this book covers a spectrum of modern materials—ceramics, woods, synthetic rubber, etc., it was selected for inclusion in this bibliography review because of its coverage of fibrous materials. This coverage, forty pages long, was written by T. D. Callinan of the I.B.M. Corporation. It discusses glass, metallic, ceramic, asbestos and organic fibers. The background conferred by this discussion will be valuable to those active in the reinforced plastics field in acquainting them with some of the basic properties, possibilities and limitations of fibers and gives information not usually found in suppliers' catalogs. The data is given in compact form with little recourse to elaborate technical discourse. A lengthy (76 item) list of references provides the reader with excellent sources of more detailed information in the field.

REINFORCED PLASTICS • • • Bibliography

Fundamental Principles of Polymerization—F. F. D'Alelio

John Wiley and Sons, Inc., 1952, 6¼ by 9¼, 517 pages, $13.50.

Adjudged Prerequisites: Organic chemistry, physical chemistry.

This book was written to serve as a basic minimum volume on polymer chemistry and it appears to fulfill its mission well. The subject is introduced gently and well and is developed evenly and thoroughly to cover plastics, rubbers and fibers. Among the areas covered are polymerization reactions, processes and kinetics; polyreactions and copolymer compositions. The book is, in general, theoretical and non-specific and very obviously written as a text in its field. For this reason and because of its excellent bibliography, it is well suited for use as a polymer "primer".

REINFORCED PLASTICS • • • Bibliography

Epoxy Resins—Henry Lee and Kris Neville

McGraw-Hill Book Co., 1957, 6¼ by 9¼, 305 pages. $8.00.

Adjudged Prerequisites: Organic chemistry, physics, strength of materials.

This is an excellent book written at a level intermediate between a general and a research level. For this reason, it has wide application as both an upper division text and as an engineering reference book. The most unusual aspect of the book is the wealth of detailed data which has been compiled, particularly in view of the relatively sparse literature publication which has existed in this field. As is appropriate to this peculiar subject, about two-thirds of the book is devoted to formulation, with the remainder given to processes. About thirty pages are devoted to the chemistry of epoxies. Other areas treated are hardener systems, diluents and plasticizers, casting, laminating coating and adhesives. Appropriately enough, a chapter is devoted to handling methods and safety precautions, an aspect to which those who have developed allergies have much respect.

REINFORCED PLASTICS • • • Bibliography

Epoxy Resins—Irving Skeist and G. R. Somerville

Reinhold Publishing Corp., 1958, 5¼ by 7¾, 293 pages, $5.50.

Adjudged Prerequisites: Strength of materials, organic chemistry.

One of the "little red" Plastics Applications Series, this is a semi-technical book intended to appeal to the "practical" chemist, manufacturer or student. Within self-imposed limits of size, scope and audience, the authors have done a superior job. The book is well balanced, complete and authoritative. It seems free from the usual errors of fact found in books of this type. The book is particularly useful to the reader in its coverage of curing systems, plasticizers and mineral fillers, for from this base the user can build adequately. The book is relatively free from a padding of "illustrative case histories" so commonly borrowed from the periodical press to fill pages. In addition to the aforementioned areas the book covers tooling, electrical embedments, adhesives, surface coatings and, of course, chemistry.

REINFORCED PLASTICS • • • Bibliography

Silicones and Their Uses—R. R. McGregor

McGraw-Hill Book Co., 1954, 5¾ by 8¼, 302 pages, $6.00.

Adjudged Prerequisites: Inorganic chemistry, physics.

This book was directed toward a readership comprised of lower division or even high school graduate technically oriented people. It is well balanced for this audience, being relatively free of highly technical terms and concepts. A great deal of effort has gone toward bestowing on the reader a good general background and understanding of the attributes of the several classes of silicones. There is no attempt to present esoteric knowledge. The book covers fluids, compounds, lubricants, resins and rubbers with the greater emphasis on characteristics and properties and a lesser emphasis on applications and chemistry.

REINFORCED PLASTICS • • • Bibliography

Phenolic Resin Chemistry—N. J. L. Megson

Academic Press, Inc., 1958, 6¼ by 10, 323 pages, $10.80

Adjudged Prerequisites: Inorganic, organic and physical chemistry.

This is unquestionably an upper division book and presumes on the part of the reader a strong working knowledge of organic chemistry. It probably represents the most esoteric effort in its field and has as its writer an authority of long standing who has remained in close contact with phenolic research on four continents. The book is well organized, strongly referenced and possesses a remarkably complete index, making it of particular value as a reference work. The book restricts itself to phenol formaldehyde polymers and includes as its topics phenolic alcohols, ammonical and related phenol formaldehyde condensates, synthesis, reaction rates, theories of molecular structure and chromatographical and fractionation methods of analysis.

REINFORCED PLASTICS • • • Bibliography

Styrene and Derivatives—R. H. Boundry and R. F. Boyer

Reinhold Publishing Corp., 1952, 6 by 8¾, 1304 pages, $22.50.

Adjudged Prerequisites: Organic chemistry, physical chemistry.

As possibly the most important single monomer in use today, styrene enjoys a unique position. Hence, it deserves special attention by the plastic student. This book is an encyclopedic work on the subject, covering between two rather widely spaced covers the complete ramifications of the subject from styrene history and manufacture to injection molding of polystyrene. This monumental effort was accomplished by not only the two credited authors, but in addition, twenty-one experts in the various fields of interest. A heavily tabulated and referenced work, it includes among its subjects, chemistry, manufacture and physical properties of styrene monomer, physical and chemical properties of polystyrene and its fabrication and molding, styrene resins (styrene-phenol, styrene-polyester, etc.) and halostyrenes.

REINFORCED PLASTICS • • • Bibliography

Laminated Plastics—D. J. Duffin and Charles Nerzig

Reinhold Publishing Corp., 1958, 5¼ by 7¾, 254 pages, $5.75.

Adjudged Prerequisites: High school chemistry, physics.

This is one of the "little red books" published by Reinhold in its Plastics Applications Series. The book is one of very few specifically on the topic of reinforced plastics, and the only one known to cover reinforced plastics as a broad subject not restricted to glass laminates. However, the emphasis is strongly upon high pressure laminates and the section on low pressure laminates is technically rather pointed toward application rather than fabrication and properties. As a consequence, it would seem desirable to use this text as a companion of Fiberglas Reinforced Plastics by Sonneborne in order to obtain a relatively complete coverage of the field. However, there is yet lacking a comprehensive serious treatment of this subject. The author discusses phenolics, melamines, silicones, epoxies and polyesters and some of the thermoplastics, and embraces fiber, paper, glass and asbestos as reinforcing materials.

REINFORCED PLASTICS • • • Bibliography

Quality Control for Plastics Engineers—L. M. Debing

(an SPE sponsored book), Reinhold Publishing Corp., 1957, 6¼ by 9¼, 142 pages, $4.95.

Adjudged Prerequisites: High school algebra.

More correctly this book might have been titled, "Statistical Quality Control", for the bulk of the book is devoted to an excellent step-by-step development of the theory and practice of large-sample statistics. In so doing, it presents methods for setting up quality control systems based on the well-known range technique. Among the areas covered are normal distribution curves, control charts for variables and attributes, and sampling inspection.

The small sample statistics of Fischer with the appropriate t and F tables are covered in the last several chapters of the book. This discussion, with its development of the theories of variance analysis, significance and the factorial experiment can be of particular value to the student in his understanding of the value of proper experiment design and interpretation, a subject which, unfortunately, is rarely treated in conventional texts.

REINFORCED PLASTICS • • • Bibliography

Textbook of Polymer Chemistry—F. W. Billmeyer, Jr.

Interscience Publishers, Inc., 1957, 6¼ by 9¼, 518 pages, $11.50.

Adjudged Prerequisites: Organic chemistry, physical chemistry, physics, calculus.

Designed by a practicing instructor specifically to serve as a textbook, this book is intended for upper division or graduate use. Consequently, it is carefully organized, annotated and referenced. It is largely theoretical, the first portion of the book dealing with physical chemistry of polymers and kinetics of polymerization. In this portion, the concepts are well and carefully developed with few of the jumps in logic so common in the more advanced texts. The second portion of the book deals with properties of plastics, fibers and elastomers. While this section of the book is lengthy, it deals with a great variety of materials, and no more than a few pages are given to any one plastic. However, these short discussions serve well as introductions without intruding unduly in the province of more detailed books on the subjects of these specific materials.

REINFORCED PLASTICS • • • Bibliography

Amino Resins—John F. Blais

Reinhold Publishing Corp., 1959, 5¼ by 7¾, 220 pages, $4.95.

Adjudged Prerequisites: Strength of materials, organic chemistry.

Inasmuch as this book has been directed to the semi-technical industrial reader, utilization of the volume is far from dependent upon knowledge of organic chemistry or stress analysis. However, such prerequisites will make the information more valuable. Lacking these prerequisites, some knowledge of plant operation or of molding would be required. The book covers urea formaldehyde and melamine formaldehyde resins rather thoroughly. In addition, a bibliography is supplied on less well known and commercially important resins such as the thiourea and guanamine. The areas of chemistry, resin manufacture and molding are covered adequately. A particularly good coverage of the subject of preimpregnate manufacture is given. Special attention is given to the field of paper reinforcement as is appropriate to its relative commercial importance. In addition to discussion of molding resins, the book covers surface coating, adhesives and paper treatment.

REINFORCED PLASTICS • • • Bibliography

Fibres, Plastics and Rubbers—W. J. Roff

Academic Press, Inc., 1956, 5¾ by 8¾, 400 pages, $10.00.

Adjudged Prerequisites: Inorganic chemistry, strength of materials, first year physics. Organic chemistry desirable but not essential.

This is a British-written book sponsored by the British Cotton Industry Research Association. It is primarily a reference text, covering high polymers but including some of the simpler plastics such as cellulose nitrate, and natural fibers such as cotton, silk and wool. Organization of the book is unusual and noteworthy. The first section provides tabular and discussion-type information on individual polymers, per se, going into structure and chemistry of the polymer and following this with information on physical properties, application and history of the materials. Natural, thermoplastic and thermosetting polymers are all noted. The second section of the book deals with properties, per se, giving the values of the range of polymers for one specific property. Properties covered include chemical resistance, plasticizers, physical properties, thermal properties, electrical properties and mechanical properties. A list of references for additional information is provided for each topic covered.

REINFORCED PLASTICS • • • Bibliography

The Properties and Testing of Plastics Materials—A. E. Lever and J. Rhys

Chemical Publishing Co., Inc., 1958, 6¼ by 9¼, 197 pages, $4.75.

Adjudged Prerequisites: Inorganic chemistry, strength of materials, first-year physics.

Finding relatively complete coverage of plastics testing between two closely-spaced covers is not very common, particularly if some actual test values are sought. This slim book does provide just this information covering physical, thermal, optical, electrical and chemical properties and testing of organic resinous systems.

The book attempts to do several things. First, it is, as pointed out by its authors, a source book in which has been compiled references to world-wide testing methods in the field. In this, it has provided its reader with a wealth of references for detailed information on tests in question. Beyond this, however, it has provided definitions of terms and a discussion of the meanings of these terms and definitions. This is a valuable contribution not usually available in either analytical texts or testing manuals. Further, it provides a critical discussion of the relative place and merit of alternate testing methods.

REINFORCED PLASTICS • • • Bibliography

Fiberglas Reinforced Plastics—R. H. Sonneborn

Reinhold Publishing Corp., 1954, 5¾ by 8¾, 240 pages, $4.50.

Adjudged Prerequisites: Strength of materials, inorganic chemistry.

Apart from the 31 page chapter on design theory by Dr. Dietz, a good high school education is adequate preparation for the use of this book. Therefore, it will serve as a basic background text for the study of reinforced plastics. As such, it introduces the reader to fiberglass and resins (principally polyesters) and some of their more elementary properties. It then proceeds to discuss manufacturing methods and tooling including handlayup but emphasizing press molding and virtually disregarding the important area of premix molding. Secondary fabricating operations are treated, including machining, fastening and painting, and a good bit of attention is given to properties of laminates and design of parts. The sections by Dr. Albert Dietz of M.I.T. and A. S. Heyser of Reed Research, Inc., are technically the most valuable inasmuch as they treat of the mathematics and economics of the material.

REINFORCED PLASTICS • • • Bibliography

Phenolic Resins—David F. Gould

Reinhold Publishing Corp., 1959, 5¼ by 7¾, 213 pages, $5.75.

Adjudged Prerequisites: Strength of materials, organic chemistry.

This is an excellent little book, notable for its organization and presentation. While it is pointed at the non-specialist, its quality is such as to make the specialist reader long for a more detailed presentation by the same author. It is probable that this is the only book still in print attempting to cover the broad field of phenolics. Having discussed the basic resoles and novolacs which comprise the backbone of the industry, the author gives a brief mention to the numerous other types of phenolics which are of general interest, the furfurols for example. He then covers resin manufacture, molding methods, laminates and casting. Also discussed are adhesives, wood products, coatings and rubber compounding. For a "little" book, the volume offers a wealth of useful (as contrasted with redundant) data. It is suggested as a basic rather than an advanced text.

REINFORCED PLASTICS • • • Bibliography

Asbestos, Its Industrial Applications—D. V. Rosato

Reinhold Publishing Corp., 1959, 5¼ by 7¾, 214 pages, $5.75.

Adjudged Prerequisites: High school chemistry and physics.

As one of the basic categories of plastics reinforcements, asbestos has a continually growing place. This book is the only one known to cover this application of asbestos. Inasmuch as its author is the outstanding American proponent of the use of asbestos in reinforced plastics, it would seem that the book is representative of the best thinking in this direction. An excellent background on the nature and source of asbestos is afforded by this volume. Particular attention may be given to the little known classifications and categories of asbestos, ill considered choice of which may result in failure where success should have resulted. Rather detailed descriptions of asbestos specifications and properties of laminates utilizing asbestos reinforcement are afforded. A discussion is given of applications of asbestos reinforced moldings. In addition to the above categories which cover about one-third of the book, discussions are given on insulation, friction materials, gaskets, and filters. A rather complete bibliography is appended but not referenced.

REINFORCED PLASTICS • • • Bibliography

Maleic Anhydride Derivatives—L. H. Flett and W. H. Gardner

John Wiley and Sons, Inc., 1952, 6¼ by 9¼, 269 pages, $8.00.

Adjudged Prerequisites: Organic chemistry, physical chemistry.

This little book is arranged as a specialized encyclopedia or a laboratory guide in maleic reactions rather than as a text or general discussion in the usual sense. One hundred sixteen reactions employing maleic anhydride or its derivatives are covered, each on a set of facing pages. Among the classes of product compounds covered are hydrocarbons, halogen compounds, metallic compounds, nitrogen compounds, oxygen-containing compounds, and sulfur compounds. In each discussion, the arrangement of information is exactly alike for easy access, with the left page heading always giving the product class and formulation and the right hand page heading always giving the class of reactant and group formula. In each instance, the specific product is described, its uses outlined and selected references given. The chemistry of the reaction is given and discussed, and a detailed outline is given of the correct laboratory procedure.

REINFORCED PLASTICS • • • Bibliography

Chemistry of the Coordination Compounds—John C. Bailar, Jr., (Editor)

Reinhold Publishing Corp., 1956, 6¼ by 9¼, 834 pages, $18.50.

Adjudged Prerequisites: Organic, inorganic, physical chemistry.

Coordination bonding, or the sharing of electron pairs, opens the door to an entire realm of inorganic polymers. While the theory is actually quite old, broad interest is new and this is a principle English language work on the subject as related to compounds. Written by Dr. Bailar with the assistance of his students and former students, this work covers the subject intensively. Among the aspects covered are theories of coordination bonding, isomerism, stereochemistry, compounds of metal ions with olefins and olefin-like substances, metal carbonyls and nitrosyls, and organic molecular compounds. The book is a highly technical, scholarly work not pointed to lower division students. An exceptionally thorough bibliography and annotation makes the book valuable as a basic reference text.

REINFORCED PLASTICS • • • Bibliography

Silicones—R. N. Meals and F. M. Lewis

Reinhold Publishing Corp., 1959, 5¼ by 7¾, 267 pages, $5.95.

Adjudged Prerequisites: Inorganic chemistry, physics organic chemistry desirable but not essential.

This is a little book and was deliberately designed to be a relatively nontechnical volume. As a consequence, it is rather general and covers its subject in less depth and in more scope than might be suspected from a cursury glance. For this reason, the book will tend to be of more value to those endeavoring to get acquainted with the general field—lower level students, nonspecialized graduates, etc.—than to the specialist. It is well written with a conscious effort to be easily and relatively effortlessly read. The largest section of the book, the section on applications, covers elastomers as well as rigid laminates, foams, adhesives and greases, etc. Other chapters cover general properties, basic chemistry, manufacture and fabrication and future prospects. A three page bibliography is provided for those interested in pursuing the subject further.

REINFORCED PLASTICS • • • Bibliography

Polyesters and their Applications—Bjorksten Research Laboratories

Reinhold Publishing Corp., 1956. 6¼ by 9, 618 pages, $10.00.

Adjudged Prerequisites: Organic chemistry.

This is probably the single most complete compilation of information on polyester resins. As such, it covers the field broadly, but suffers from being an apparent literature survey effort rather than the product of applied effort. The book contains what is undoubtedly the most complete bibliography extant on the subject, referencing several thousand sources. For this reason, error has likely been introduced, making the book of more value as a general reference than as an authoritative source. Among the subjects covered are raw materials, manufacture, catalysis, reinforcement, manufacturing of reinforced plastics and applications. The book is exceedingly broad in its coverage and for this reason, tends to be undetailed in specifics. This fact may make it of particular value in educational systems where it may be of more value than in applied engineering.

REINFORCED PLASTICS • • • Bibliography

Vinyl and Related Polymers—Calvin E. Schildknecht

John Wiley & Sons, Inc., 1952, 6¼ by 9¼, 723 pages, $16.50.

Adjudged Prerequisites: Organic chemistry, physical chemistry.

This advanced volume on vinyl compounds provides an intensive source of information on the formulation and compounding as well as on the chemistry of this class of polymers. Owing to its relative importance, styrene (vinyl benzene) is given considerable attention in its various applications—as the monomer for polystyrene, as a component of synthetic rubbers, or as a comonomer for alkyd thermosetting resins. It will be appreciated that if to the aforementioned resinous systems be added those systems commonly known as vinyls—vinyl chlorides, etc., a very substantial portion of the plastics market indeed is represented, hence the importance of this volume should not be minimized. Among the additional areas covered are methacrylics, acrylonitrilics, vinyl acetates, ethylene high polymers, and sulfur and nitrogen vinyl compounds. The volume is intensive and scholarly and should not be considered for lower division use.

REINFORCED PLASTICS • • • Bibliography

Principles of High-Polymer Theory and Practice—A. X. Schmidt and C. A. Marlies

McGraw-Hill Book Co., Inc., 1948, 6¼ by 9¼, 743 pages, $12.50.

Adjudged Prerequisites: Organic chemistry, physical chemistry, strength of materials, calculus.

This is definitely an upper division text intended to provide a broad non-specific chemical engineering background in polymer chemistry. Accordingly, it de-emphasizes the mechanics of resin manufacture and emphasizes the physics and engineering of polymers. It is an excellent book which can serve as a text and a continuing reference to the graduate in plastics. Every effort has been made to provide a discussion and data on a quantitative rather than a qualitative basis and there is a strong usage of the engineering rather than the chemistry approach, demanding a reasonable background in stresses and in physics. Among the areas covered are molecular forces, polymer formation and structure, molding, adhesives and resin product development. Mechanical, electrical, thermal, and optical properties are discussed in detail.

REINFORCED PLASTICS • • • Bibliography

Engineering Properties and Applications of Plastics—Gilbert F. Kinney

John Wiley & Sons, Inc., 1957, 6¼ by 9¼, 278 pages, $6.75.

Adjudged Prerequisites: Organic chemistry, strength of materials, physics.

The problem of covering the properties of the entire field of plastics by a single individual between two covers is a difficult one at best, and it is not surprising that over the years so few individuals have succumbed to the temptation. This volume is a well published, well edited but rather academic version of the approach. The field has been covered in reasonable broadness but with particular concentrations on areas to which information is more readily obtained in the literature. Epoxy, for example, is given about two pages of comment, and the discussion of polyesters tends to emphasize saturated types described in the patent literature and molding methods rather obsolete at this time. Of the books tending to be broad in coverage, this is not one of the more authoritative.

REINFORCED PLASTICS • • • Bibliography

The Furans—A. P. Dunlop and F. N. Peters

Reinhold Publishing Corp., 1953, 6¼ by 9¼, 867 pages, $22.50.

Adjudged Prerequisites: Organic chemistry, physical chemistry.

A definitely upper division book, this is an authoritative and monumental treatise on furans and furfurols by two of the most qualified men in the field. The furans, notable for their chemical and heat stability have not enjoyed the usage which they have possibly deserved, although the reason for this is not entirely clear. The authors treat the chemistry of furan and its homologs, halogen derivatives and nitro compounds. They discuss the alcohols, and carboxylic acids, and furan hydrogenation. The chemistry, properties and characteristics are thoroughly tabulated and described. Furfurol derivatives including resins, cements, adhesives and coatings are discussed in detail. Some of the applications are described. An extremely extensive patent listing appended will be of possible value in further study of the field.

REINFORCED PLASTICS • • • Bibliography

Polymers and Resins—Brage Golding

D. Van Nostrand Co., Inc., 1959, 6¼ by 9¼, 744 pages, $15.00.

Adjudged Prerequisites: Strength of materials, organic chemistry, physical chemistry.

An upper division book, this was written specifically to serve as a text on polymers and resins. For this reason, it tends to emphasize the theoretical and mathematical aspects of the subject. Possibly for the same reason, it is well organized and clearly expressed. About half the book is devoted to theoretical aspects of polymer chemistry—characterization, formation, polymerization systems and molecular structure. The balance of the book is devoted to chemical engineering—resin and polymer manufacture, fabrication and processing. The section on polymer manufacture is of particular interest in that it is one of the few sources of detailed discussion on polymer manufacturing practice. Among the resin classes covered are cellulosics, phenolics, polyesters, epoxies, urethanes silicones, vinyls and furans.

ADDITIONAL TITLES

Engineering Properties and Applications of Plastics—G. F. Kinney

John Wiley and Sons, 1957, 278 pages

Compression and Transfer Molding of Plastics—J. Butler

Interscience Publishers Inc., 1959, 230 pages

Manne Design Manual for Fiberglas Reinforced Plastics—Gibbs and Cox, Inc.

Mc Graw Hill Book Co., Inc., 1960, 200 pages

Also—

Modern Plastics Encyclopedia and The 15 Volumes of the Papers Presented at the Annual Technical and Management Conference of the Reinforced Plastics Division of the Society of Plastics Industry, Inc.

Technical Papers Volumes I-VI presented at the Annual Technical Conferences of the Society of Plastic Engineers.

—— ■ ——

Edited by **George Lubin,**
Grumman Aircraft Co.

STATUS REPORT:

Monsanto plastics for packaging & the food additives amendment

As part of Monsanto's continuing responsibility to customers and to package users, we present this up-to-the-minute status report of Monsanto plastics for food packaging and a brief definition of terms important to a general understanding of the Food Additives Amendment, which became effective March 6, 1960 ■ Monsanto's extensive research and development over the years have resulted in many plastic formulations from ingredients which are generally recognized as safe or which have prior sanction or which have no reasonable expectation of migration ■ By using the Monsanto plastics listed on the following page, you can be certain of packaging materials which comply with the Food Additives Amendment. We will keep you informed of additions.

MONSANTO DEVELOPER IN PLASTICS

The Status of Monsanto Plastics—November, 1960

PRODUCTS	BASIS FOR RECOMMENDED USE IN FOOD PACKAGING
LUSTREX® STYRENE PLASTIC	
General Purpose Molding Grades	
Hi-Flow 55, Hi-Flow 66, Hi-Flow 77, Hi-Heat 99	Generally recognized as safe and prior sanction by FDA.
Impact Molding and Extrusion Grades	
Hi-Test 42 Type, Hi-Test 88 Type, Hi-Test 48 Type, Hi-Test 180 Type	Extension granted by FDA until March 5, 1961 (Long term feeding studies highly favorable)
MONSANTO POLYETHYLENE (NATURAL)	
Injection and Blow Molding Grades: 51 805, 52 935, 60 9752, 80, 705	Prior sanction by FDA.
Film Extrusion Grades: 30 37 18300, 31 38 19706, 32 706 23406, 33 10406 25706, 34 13406 26706	
Extrusion Coating Grades: 406, 537, 73	
VUEPAK® F CELLULOSE ACETATE	Generally recognized as safe and prior sanction by FDA.
OPALON® VINYL RESINS	
300, 330 FM, 300 FM, 410	Prior sanction by FDA.
Polyvinyl chloride acetate copolymers	
506, 510	Prior sanction by FDA.
SCRIPTITE®	
Paper and Paper Board Coating Resins	
50, 52, 53, 54	No reasonable expectation of migration when used as wax-holdout resin.
40 (Urea Resin)	Prior sanction by USDA Poultry Division as wet strength poultry package resin.
33 (Melamine Resin)	Prior sanction by FDA.
RESIMENE®	
883 (Melamine Resin)	Prior sanction by USDA Meat Inspection Division for lard cans.
U901 (Urea Resin)	Prior sanction by FDA.
LYTRON®	
Latex Paper Board Coating Resins	
6, 6-A	Not subject to regulation when used in single use disposable containers. Petition being prepared for regulation of all food packaging uses.
RESINOX® PHENOLIC RESIN	
P-97	Prior sanction by USDA Meat Inspection Division for lard cans.

DEFINITIONS

of terms important in understanding the Food Additives Amendment.

Food Additives Amendment—1958 Amendment to the 1938 Federal Food, Drug and Cosmetic Act. It requires, for the first time, that any chemical compound in food, whether intentional or incidental, must be proved safe before the food is put into interstate commerce. The amendment became effective March 6, 1960.

Food Additives—All chemical compounds in food are *not*, however, in *legal* sense food additives. Compounds with prior sanction or which are generally recognized as safe are specifically excluded by the new statute from the category of food additives.

Prior Sanction—Before the 9/6/58 enactment of the Food Additives Amendment, the Food and Drug Administration and divisions of the United States Department of Agriculture had only limited authority to approve use of chemical compounds in foods. Favorable response to a request for approval normally meant an informal letter of no objection—now classified as a prior sanction—exempt under the new amendment.

Generally Recognized as Safe—The FDA interprets this to mean that it is the widely held opinion of acknowledged authorities that a given chemical compound is safe in human food. FDA has published in the Federal Register, lists of compounds which are considered generally recognized as safe.

No Reasonable Expectation of Migration—It is obvious that chemical compounds not in food cannot be food additives. But the definition of "zero" content requires scientific judgment. No reasonable expectation of migration (of pharmacological significance) realistically recognizes that infinitesimally small amounts of certain chemical compounds may be and generally are present in processed foods without hazard.

* * *

A special report on food packaging colorants has been prepared for package manufacturers using colorants in their packages. For this report, write to Monsanto Chemical Company, Plastics Division, Room 773, Springfield 2, Massachusetts.

HOW KODIAK PUTS A TOUGH DESIGN ON ICE

"Molds without draft . . . vertical surfaces . . . sharp corners and intricate detail . . . maximum insulation . . . they're a snap with ADM resins."

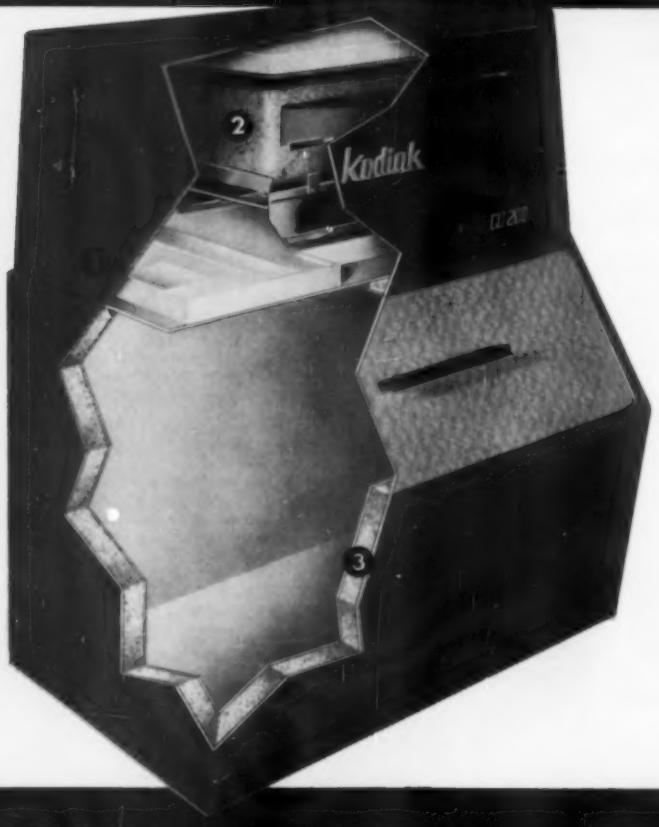
True to its name, the Kodiak Ice Maker was a real bear to knock out in fiberglass . . . and a real bear to insulate. But Kodiak Industries, St. Paul, Minnesota, is doing it with tremendous success. By using plastic throughout, Kodiak makes an automatic ice cuber that's unique not only for the crystal purity of its ice cubes, but for strength, beauty, insulation, and seamless sanitation.

Says Kodiak Production Manager, Red Williams: "Every part in our machine is a headache to produce . . . so tough, in fact, that out of all the different laminating and foaming resins we tried, only ADM's do the job to our satisfaction."

1 **OUTSTANDING WET-OUT** "ADM Aropol resins wet-out almost instantly. They make rolling a snap, prevent air bubbles from forming under the gel coat. As a result, even the nearly square corners of our streamlined box are extremely strong and smooth."

2 **"THE SEALZIT GUN** has several advantages over other guns we've tried, but most important to us, it shoots the glass out under enough pressure to smack it into the tight spots and to make it stick to the vertical surfaces. And the Sealzit gun is easier to handle . . . keeps labor and material costs down."

3 **1:1 RATIO FOR FOAM** "With ADM's rigid foam resins, insulating the Kodiak is no trick at all. We can use a 1 to 1 mix, which is ideal for handling with virtually any equipment. Temperature isn't critical either with these low viscosity resins. We get excellent foam uniformity and good cure in our insulation without the need of heating or cooling the resin lines. No other resin gives you so much latitude."



WHATEVER YOUR LAMINATING OR FOAM REQUIREMENTS, ADM HAS A RESIN THAT'S IDEAL FOR THE JOB. RELY ON ADM FOR DEPENDABLE QUALITY AND SERVICE ALWAYS . . . FOR NEW RESEARCH DEVELOPMENTS FIRST.

Archer-Daniels-Midland

752 Investors Building
Minneapolis, Minnesota

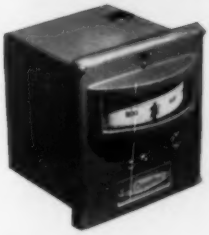
CHEMICAL GROUP
Resins • Plastics • Industrial Chemicals

Wheelco Industrial Instruments Division

SERIES 8000
Single point indicating-recording-controllers and multipoint indicating-recorders. Electronic potentiometer type.

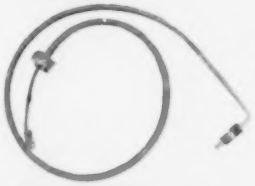
SERIES 2000
Round chart electronic potentiometer recorders and recording-controllers. Pen speeds of 1, 4, and 20 seconds.

SERIES 400
Capacitrols for indicating and controlling temperatures, voltages, current, speed, pressure and similar variables.



MODEL 297
Capacitrols specially designed for plastics applications. "Electronic Link" no-contact control. Plug-in terminal panels.

MODEL PT 58
Dynisco Pressure Transducer. Designed specifically for thermoplastic processes.



THERMOCOUPLES
Single and dual-element thermocouples available for plastic industry requirements.

Whether you are a builder or a user of molding and extrusion machinery, Wheelco's complete line of performance-proved recorders, controllers, indicators, pressure transducers, and complete systems will fit your instrumentation requirements. The quality you get when you specify Wheelco has made Wheelco the industry's largest supplier of molding and extrusion instrumentation.

THE MARK OF QUALITY

BARBER COLMAN

BARBER-COLMAN COMPANY
Wheelco Industrial Instruments Division
Dept. K, 1575 Rock Street, Rockford, Illinois, U.S.A.
BARBER-COLMAN of CANADA, Ltd., Dept. K, Toronto & Montreal • Export Agent: Ad. Auriema, Inc. N.Y.

Bubble Trouble?

Good air release and bubble break in plastisols mean an end product free of imperfections. The new Mark BB stabilizer just developed by Argus solves this problem better than any other stabilizer available.

Mark BB is a multi-purpose stabilizer. In addition to its excellent bubble break properties, it gives outstanding heat and light stability, low viscosity, and viscosity stability throughout processing.

What's *your* current problem? Bubble break? Low temperature stiffening? Toxicity? Getting better resistance in electrical compounds at less cost? Lack of clarity in rigids?

Don't sit with it. Simply call Argus. Chances are the answer lies in one of our present Mark stabilizers or Drapex plasticizers. If not, we'll find it for you in our lab.

Argus Has the Answer

Technical bulletins and samples on request

ARGUS CHEMICAL Corporation 633 Court Street, Brooklyn 31, N.Y. Branch: Frederick Building, Cleveland 15, Ohio

Rep's.: H. M. Royal, Inc., 11911 Woodruff Ave., Downey, Cal.; Philipp Bros. Chemicals, Inc., 10 High St., Boston; H. L. Blachford, Ltd., 977 Aqueduct St., Montreal.
European Affiliates: SA Argus Chemical NV; 33, Rue d'Anderlecht, Drogenbos, Belgium – Lankro Chemicals, Ltd.; Salters Lane, Eccles, Manchester, England.

SPE JOURNAL

Every Month—the *significant* NEWS
OF PLASTICS ENGINEERING

Designing Thermoplastic Structural Components

This article describes two methods for predicting the load-carrying ability of thermoplastics for any combination of time and temperature. The methods should go a long way towards enabling design engineers to take the guesswork out of designing with plastics

With the very rapid increase in the use of plastics, have come many applications which require a high quality of manufacture and long term performance under stress. These applications include such things as furniture legs, home water system filters, refrigerator and freezer components, automotive parts, pipe etc. Good design and engineering data are becoming increasingly necessary to insure success in these applications. Plastics are maturing as engineering materials, and engineers have every right to expect the necessary engineering data to be available to enable them to make best use of these versatile materials. Such data on strength properties are not generally available today.

Plastics are Viscoelastic

The methods of test that have been used to measure the strength properties of plastics are, in general, useful only for controlling the quality of a product or for identifying a material. They have not given the engineer the data he needs to design plastic parts with success. The reason for this, of course, is that the strength properties of plastics are time dependent (as are most other engineering materials) and data obtained in short time tests have not been related to long term behavior.

The well-known viscoelastic behavior of plastics, as typified by the Maxwell Model, accounts for the fact that short term properties do not necessarily correlate with long term properties. Short term properties reflect mostly the behavior of the elastic (spring) portion of the plastic and does not account for the creep or stress relaxation of the viscous (dash pot) portion of the plastic. On a long term basis, the viscous behavior is most important, and for shorter periods of time, the elastic properties become more important. For example, if the application involves a shock or rapid type of loading, then the elastic properties are most important.

W. D. Harris and Wendell W. Burlew,
Dow Chemical Co., and **Frederick McGarry,**
Massachusetts Institute of Technology

The variables, which control the amount of stress relaxation or creep taking place and the relative importance of the viscous properties as opposed to the elastic properties, are:

1. **The magnitude of the stress.**
2. **The length of time the stress is applied.**
3. **The temperature of the part.**

Increasing any of these variables increases the rate and the amount of stress relaxation or creep taking place. Many investigators have studied the phenomena of creep and stress relaxation on a research basis and these concepts are not new. However, the information in this article examines the mechanisms as they pertain to materials having specific sales designation. It is the purpose of the article to show how useful design data may be obtained on the specific materials being used, not data on generic materials such as polystyrene, polyethylene, etc. The article further defines the relationship of these variables to the behavior of the plastic and to show how the data obtained can be used by the designer and engineer to make better plastic parts.

Equipment and Test Procedure

Two very simple and inexpensive types of apparatus have been developed to study the relationship of time, temperature and stress. The balanced-beam creep and relaxation instrument was designed and built at The Dow Chemical Company, and the square donut for relaxation studies was designed at Massachusetts Institute of Technology.

Balanced-Beam. For stress relaxation studies, this instrument (*Figure 1*) differs from a simple beam in that stops are provided over and under the outer end of the beam to

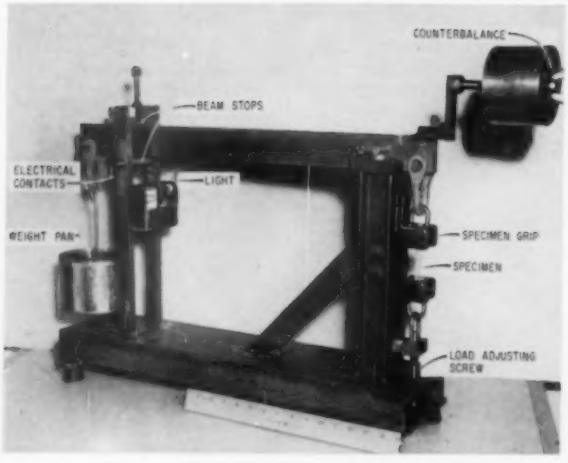


Figure 1. Balanced beam stress-relaxation unit

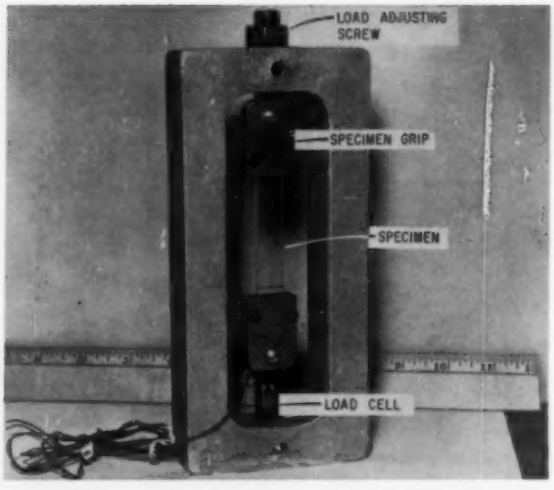


Figure 2. Square donut stress-relaxation unit

allow only one or two thousands inch clearance in which the beam can swing. Before the specimen is inserted in the grips, the weight on the beam rests on the bottom support. Initially then, the weight needed to load the specimen can be placed in the weight pan and it will all rest on the lower beam stop. The specimen can then be placed in the grips and the load transferred from the beam stop to the specimen by turning the threaded screw holding the lower specimen grip to the base of the instrument. This brings the beam into initial balance as indicated by the flickering light as the electrical contact points begin to break. The initial stress and strain are recorded at that point. As time passes and the specimen relaxes, it loses its ability to maintain the stress and the load of the weight pan begins to rest more and more on the lower beam stop. To obtain subsequent readings of how much stress is still being carried by the specimens, weights are removed from the weight pan until the beam again comes into balance. The weight remaining in the pan is again being carried by the specimen and the resulting stress can be calculated.

If it is desired to measure creep instead of stress relaxation, then the lower beam stop is removed and the appropriate dead weight is applied to the specimen. Strains are measured using a cathetometer having a vertical travel of at least two inches and reading to an accuracy of at least 0.0001 inches. A telescopic attachment is useful with the cathetometer in order to get some depth of field and make it possible to take measurements from a distance. In our program, some cross checking is being done on samples placed in creep, but the bulk of the data are being obtained by stress relaxation techniques since the change in stress is easier to observe than small changes in strain.

Square-Donut. The instrument (*Figure 2*) developed at MIT by Dr. Rod Andrews and Mr. Roger Currans, is somewhat simpler and more economical to produce than even the balanced-beam. In addition, the size permits the use of large numbers of these instruments in a very small space, thus greatly shortening the time required to complete a program. It is, however, limited to studies of stress relaxation although with some modification it can be used for creep studies.

The instrument is a substantial casting of aluminum in the shape of a square-donut. One end is machined perpendicular to the lengthwise direction and a 1/2 inch hole is drilled through the center of this end, also in the lengthwise direction. A threaded bolt through the hole provides a means of applying the initial stress. Attached to the bolt is one of the specimen grips made from pieces of ordinary flat mill files. The other grip is attached to a strain gage load cell which is in turn attached to one end of the square-donut. The change in stress is measured using a static strain indicator in conjunction with the strain gage load cell. Each load cell must be carefully calibrated before use (*Figure 3*).

Reproducibility between these two instruments for measuring stress relaxation is excellent as shown by *Figure 4*.

Careful Specimen Preparation is Important

It is well known that the injection process (because of orientation and differential cooling) produce rather complex strain patterns in the plastic as it flows into the mold or through the die. The resultant strain patterns are seldom, if ever, the same in any two moldings. It is also known that the molding strains will have a pronounced effect on the performance of the part, particularly if a chemical environment is imposed. It was decided to eliminate this variable and determine first of all what the material itself, unchanged by the method of fabrication, could do and then introduce the fabrication variable.

Compression moldings, if they are carefully prepared, will have little or no orientation or thermal strain in the part. The molecular arrangement will be completely random and the properties therefore, will be representative of the base material. It has been found also that the properties of compression moldings, while not exactly the same, do closely approximate those of extrusion and vacuum formed moldings. *The data obtained on compression moldings then, are directly applicable to the important field of extrusion and vacuum forming.*

As stated before, the specimens are carefully prepared by compression molding the plastic into sheets, so as to produce no orientation or thermal strain. These sheets can best be prepared in a mold like a piston and cylinder arrangement (*Figure 5*) so that positive pressure can be maintained on the plastic throughout the heating and cooling cycles. Normally, they are made in 1/8" thickness. If properly prepared, the sheets will show no warpage when placed in an oven and heated above the second order transition temperature of the plastic.

The sheet can then be sawed into 3/4" wide strips and carefully machined into the final cross-sectional dimensions of 1/8" by 1/2". Care should be taken in sawing and machining to see that the specimens are not touched directly by the fingers. The behavior of some plastics is noticeably altered by the oil of the skin. The operator nor-

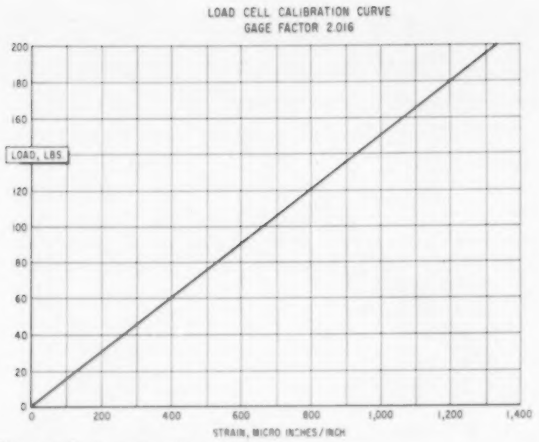


Figure 3. Load cell calibration curve.

mally wears a pair of clean, white cotton gloves when preparing specimens.

It has been found too, that in conducting the test, control of temperature is very important. A one degree Fahrenheit change in temperature may cause a change in stress in the specimen of as much as 10 or 15 psi. The test equipment consequently, is housed within a glass cabinet in a temperature controlled room. This smooths out or eliminates the cycling normally found in a temperature controlled room.

The precision and reproducibility of the stress relaxation tests are such that only spot checking need be done as the program proceeds. If a faulty specimen is encountered or if it is not strained uniformly, the relaxation curve will be obviously displaced from its proper position and can be discarded.

Data Obtained by Stress Relaxation Studies

When a specimen is placed under a constant strain, the resultant stress in the part will gradually decrease with time. If this is done at a series of strain levels, a family of relaxation curves will be obtained such as the ones for Material A (*Figure 6*). It will be observed that at some time period, failure in the specimen will occur. The time required for failure to occur is dependent on the magnitude of the strain. It should also be pointed out here that the appearance of cracks in the specimen does not necessarily mean that it is about to fail structurally. There may be a considerable lag between the appearance of cracks and actual failure.

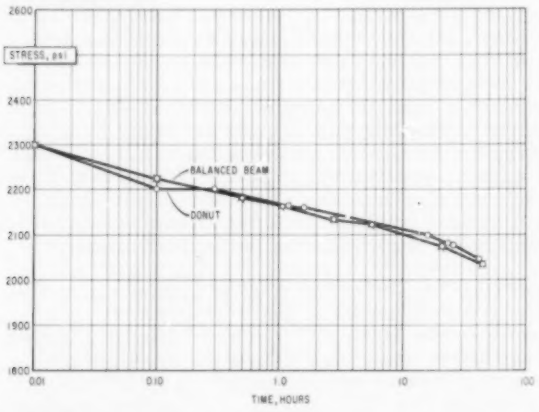


Figure 4. Comparison of relaxation curves—balanced beam vs. donut

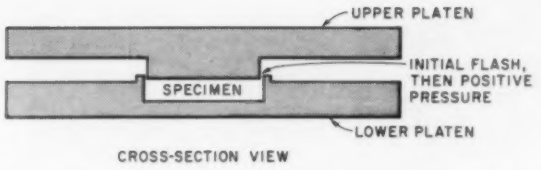


Figure 5. Semi-positive pressure compression mold

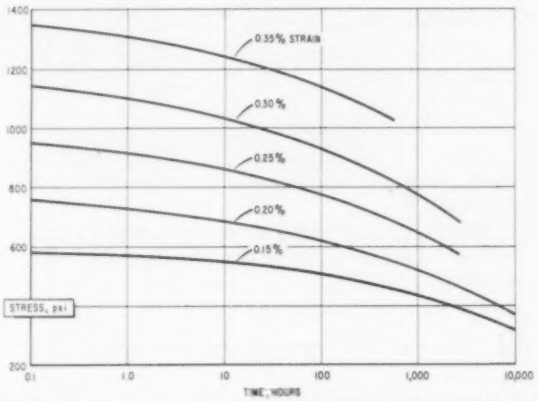


Figure 6. Stress-relaxation of Material "A" @ 73.4°F.

These data can be replotted in three dimensional form to show the relationship of stress, strain and time as in *Figure 7*. The surface created in this plot then represents the performance or behavior of the plastic under stress. The indicated failure points represents the limits of usefulness of the material as a structural member. If these limits are exceeded for any combination of stress-strain-time, the part must fail.

Another method of presenting the data for use, is to draw vertical intercepts at different time intervals on the stress relaxation family of curves plot, as shown in *Figure 8*. The stress and strain obtained at the points of intersection of the relaxation curves with the vertical time intercepts can be replotted as a family of stress-strain curves at various time intervals (*Figure 9*). The slope of these stress-strain curves can be calculated to obtain the "apparent" modulus of elasticity and replotted as a function of time, as shown in *Figure 10*. From the simple relationship, Modulus $= \frac{\text{stress}}{\text{strain}}$ for tensile forces, compression forces and bending forces

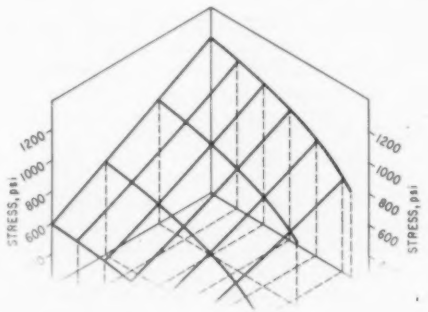


Figure 7. Stress-strain-time relationship for Material "A"

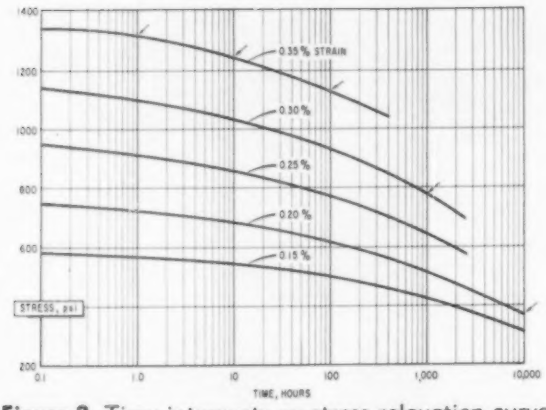


Figure 8. Time intercepts on stress-relaxation curves of Material "A"

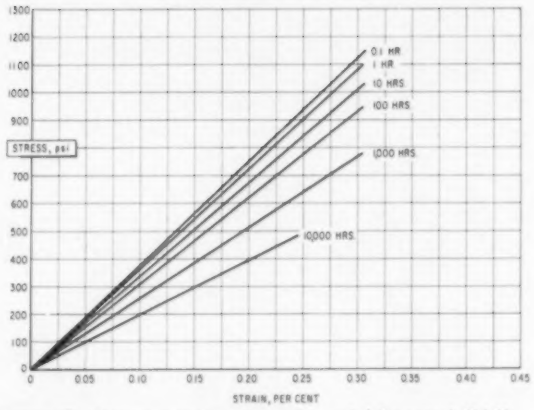


Figure 9. Stress-strain-time plot of Material "A"

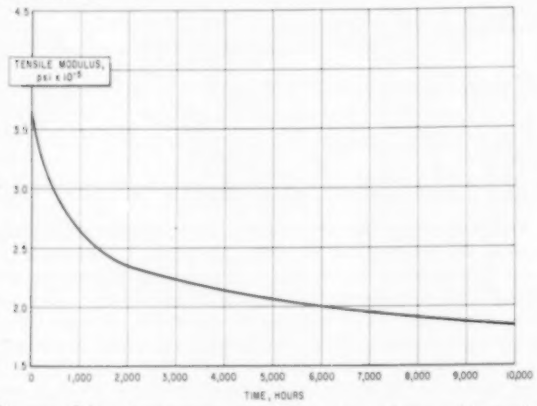


Figure 10. Apparent modulus vs. time—Material "A"

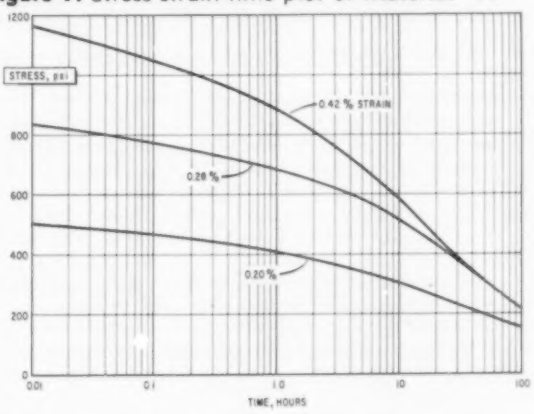


Figure 11. Stress-relaxation of Material "A" at 125°F.

the stress and strain relationship can be determined for any desired time.

A series of three dimensional or apparent modulus curves can also be prepared to relate stress and strain to temperature. Actually, for most plastics, if the temperature is held below the second order transition temperature of the material, an increase in the temperature has the effect of compressing the time axis. *One can obtain at moderately elevated temperatures in a few hours, the same results that would be obtained in weeks at room or lower temperatures* (*Figure 11*).

If this relationship of temperature is known, then data can be obtained at a greatly accelerated pace at elevated temperature and transposed to other temperatures thus, further simplifying this kind of a test program.

How Test Can be Put to Practical Use

Problem: Having a part that has already been produced and knowing the stress or strain that is to be applied, the expected life of the part can be calculated. For example, assume a pressure vessel has been produced from Material A. It has a uniform wall section thickness of 0.250" and an internal diameter of 4". It is to operate at room temperature and at a maximum pressure of 75 psi. From hydrostatic pressure tests and torque measurements, it has been determined that failure will be in the meridional direction and a stress of 50 psi will be imposed on the material when the threaded cap is screwed on the top of the cylinder. What will the total fiber stress in the meridional direction be, and will the material be able to maintain that stress for a period of ten years?

Solution: The formulas for thick wall cylinders apply in this case and the meridional stress is obtained from the formula $S_m = p \times a^2$ divided by $b^2 - a^2$, where a = inter radius of the vessel, in., b = outer radius of the vessel, in. p = internal pressure, psi. $S_m = 75 \times 2^2$ divided by $2.25^2 - 2^2 = 282$ psi. Add to this the 50 psi prestress applied when the vessel is assembled to get the total fiber stress of 332 psi. Referring to *Figure 7*, it is necessary to extrapolate the relaxation curve, one decade of time to obtain limiting stress for 10 years of service. It is found that the 332 psi stress is well within the allowable stress of 400 psi.

On the other hand, if a part is to be designed and the designer knows how long the part is to last, he can calculate either the stress the part can carry or the amount of creep that will take place. *These can be related to the wall section thickness in order to obtain the desired results.* Example, using the preceding problem but this time solving for a minimum wall section thickness required and holding the inside diameter constant at 4 inches, it is found from *Figure 7* that the maximum allowable working stress is 400 psi for 10 years service. Substituting this into the equation for meridional stresses and solving for "b", wall section:

$$b = \frac{\sqrt{pa^2 + S_m a^2}}{S_m}$$

$$= \frac{\sqrt{(75)(2)^2 + (300)(2)^2}}{300}$$

$$= \sqrt{5} = 2.225 \text{ inches}$$

Short-term, high-temperature tests predict long-term room-temperature performance of ABS, vinyl chloride, and methyl methacrylate polymers by supplying more precise data on . . .

Stress Relaxation and Creep Measurements of Some Thermoplastic Materials

R. L. Bergen, Jr., *Naugatuck Chemical, Div. of United States Rubber Co.*
and
W. E. Wolstenholme, *Research Center, United States Rubber Co.*

One of the important factors limiting the use of thermoplastics in load bearing applications is the lack of long term engineering data. It is well-known that thermoplastics will creep when placed under load and that this creep is accelerated by increased temperature. However, the engineer desires specific data for each material which will give him safe working stresses to avoid either excessive creep or rupture of any designed part. One method of obtaining this data is to place the material under test for 10,000 to 100,000 hours, but this approach has its practical limitations. It is, therefore, highly desirable to develop accelerated test methods for obtaining this data. This article represents a dual approach to this problem. By measuring both stress relaxation and creep of a number of thermoplastics, methods have been developed for obtaining long term data from short term tests.

Experimental

A flexural stress relaxometer that records the stress loading and stress decay has been developed for studying the effect of temperature and other variables on the long term properties of commercial plastics. Stress relaxation, wherein the sample is held at a fixed deformation and the decay of stress is measured as a function of time, has the advantage over a creep test in that only one stress-measuring apparatus is required for a large number of samples. This is effected by mounting each sample in an individual 1-½" channel iron holder. This assembly is then clamped in the oven of the stress relaxometer. The sample is deflected as a cantilever beam to a pre-set deformation by a wire and pulley system activated by a spring-loaded mechanical plunger. The force required to bend and keep the sample deflected is measured by an unbonded strain gauge transducer attached to one end of the wire. The transducer output is amplified and recorded on a strip chart recorder. After the initial 30 minutes of testing the bent sample is secured in the deflected position by means of a machine screw in the channel iron sample holder and removed from the stress relaxometer until time for a subsequent reading. Readings are taken on a log-time scale. With automatic recording the earliest stress value read from the strip chart is at 0.08 sec. Between measuring periods the samples are stored in circulating air ovens maintained at test temperatures of 120°, 100°, 70° and 50°C or in a constant temperature room at 23°C. Subsequent readings of the residual force required to keep the sample in its bent position are obtained as follows: sample and holder are clamped in the stress relaxometer oven and loaded by a chainomatic with additional weights as required until the load is sufficient just to break an electrical contact between the holding screw and the end plate on the sample. The computed pull is recorded as the residual value of stress in the sample at that time.

Dead weight pull vs. deflection curves at testing temperatures are obtained prior to testing in order to establish settings for the stress relaxometer and determine the elastic limit of the material to be tested. All samples are tested within their elastic limit. Duplicate samples were run at each test temperature.

Although creep data are more difficult to obtain compared with stress relaxation results, the data are more meaningful to the engineer. From this data a safe working stress can be computed for any temperature to avoid excessive creep or rupture within the time limit in which the data are valid. Because the apparatus is occupied by the sample for the entire duration of the creep test, it would be desirable for economy of time and equipment to be able to run short term tests to predict long term performance. It would be even more desirable to convert stress relaxation results to creep curves.

The creep tester is a six position unit for applying a dead load to a sample and measuring its elongation using a cathetometer. The lower jaw in each position can be moved up or down over a limited range by a threaded screw. The

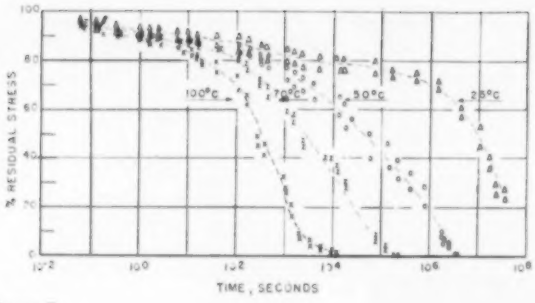


Figure 1.

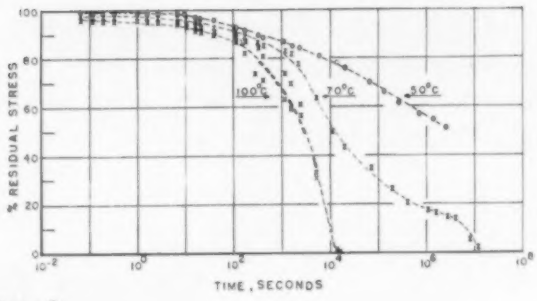


Figure 2.

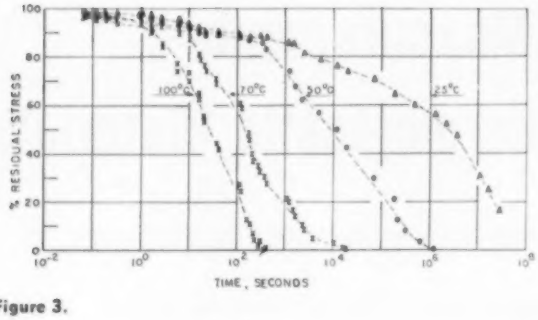


Figure 3.

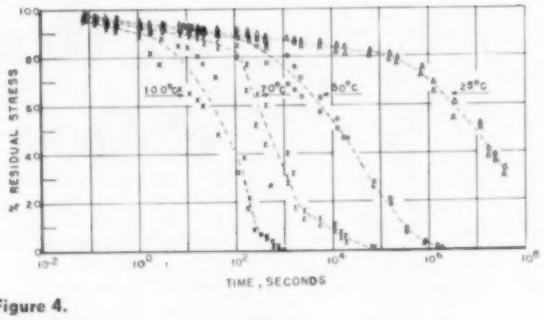


Figure 4.

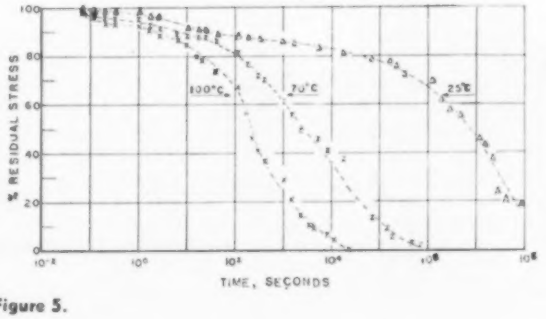


Figure 5.

Figures 1 through 5. The five groups of curves, above show stress relaxation results for ABS, PVC, and MMA polymers. Identification as follows: Figure 1, ABS polymer B, Figure 2, ABS polymer HTHT, Figure 3, ABS polymer-L, Figure 4, PVC copolymer 8750, and Figure 5, MMA polymer V-100. The stress decay is plotted as percent residual stress. All data show the sigmoid curve on a log-time basis

upper jaw is hung from one end of a beam and weights are hung from the other end to apply a tensile load from 1 to 2000 pounds. The jaws and sample are enclosed by a constant temperature air bath. Percent elongation is measured by placing bench marks on the samples and determining the distance between the marks with a cathetometer which reads to 0.0001 inch. Readings are taken on a log-time scale beginning at 1 minute. Short-term tests were terminated at 50 or 96 hours while for longer term tests, measurements were continued to 1010 hours. In the majority of the tests, samples were removed from the apparatus before they had fractured. In the earlier portion of the testing program five or six samples were run at each stress and temperature. Although there was some scatter in the data, it was decided that for economy of time only three samples would be run at each stress. With this procedure the data still retained the desired precision. In some instances, tests at a given stress were repeated at a later date with three additional samples. The repeat tests were always in good agreement with the original results. All the curves shown represented dead load creep. No correction was made at high elongations for increased stress due to decreased cross sectional area. From a practical point of view high elongation represents failure so the data do not have much significance beyond about 5% elongation.

The materials for which test results are reported are as follows: Kralastic[a] B, Kralastic[a] HTHT and Kralastic[a] L, ABS polymers of different acrylonitrile-butadiene-styrene ratios; Kralac[a] H, a styrene-acrylonitrile copolymer; Geon[b] 8750, a rigid poly (vinyl chloride); and Plexiglas[c] V100, poly (methyl methacrylate). These materials are all commercially available thermoplastics. Stress relaxation tests were run on 8-½" x ½" x ¼" bars cut from compression moldings. Creep tests were run on standard injection molded tensile bars (0.500 inch wide by 0.130 inch thick at the center section).

Results

Figures 1 through 5 show the stress relaxation results for ABS polymers B, HTHT, and L, poly (vinyl chloride) 8750 and poly (methyl methacrylate) V100, respectively. The stress decay is plotted as percent residual stress. All the data show the characteristic sigmoid curve on a log-time basis. However, variation of the shape of the curves at each temperature clearly indicates that the conventional temperature superposition by a shift along the log time axis (1, 2)

[a] Registered Trademark—U. S. Rubber Company.
[b] Registered Trademark—B. F. Goodrich Chemical Company.
[c] Registered Trademark—Rohm & Haas Company.

is not applicable to these stress relaxation data. It should be noted that the fact one can remove the samples from the relaxometer makes it possible to make measurements over 8 or more decades on the log time scale. It is planned to continue the tests at each temperature until the sample has relaxed completely. This technique is, therefore, considerably more comprehensive than that of other workers (3, 4, 5) who generally terminate their tests after about 4 decades on the log time scale. Actually, in some cases (3) much of the data is taken over only one or two decades at many different temperatures. Thus, one wonders how well some of these data would fit if it were taken over a longer time interval. Similar remarks can also be made about dynamic tests. Maxwell (6) has shown that his data for poly (methyl methacrylate) cannot be superimposed by a simple shift along the log time axis and has proposed that three dimensional modulus-time-temperature plots be used. His data were taken over slightly more than five decades of frequency from −30°C to +80°C. On the other hand, Ferry (7) has superimposed data for poly (isobutylene) which were obtained at a number of temperatures but over less than two decades of frequency. Another factor to be considered is the relationship of the testing temperature to the glass transition of the polymer under test. Williams, Landel and Ferry (8) claim that their superposition method is valid only from T_g to $T_g + 100$°C and Tobolsky (3) has reiterated that the time-temperature superposition principle is probably only partially valid at temperatures close to T_g and lower.

Since the conventional time-temperature shift could not be applied to the data shown in *Figures 1-5*, a different approach was necessary. The simplest mechanical model for representing stress relaxation consists of a spring and dashpot in series, the Maxwell model. Theoretically, any stress relaxation curve can be fitted by an infinite number of these spring-dashpot elements in parallel (9).

For the data presented here it was hoped that each stress relaxation curve could be fitted by a small number of these elements. By plotting log stress vs. time and using the method of residuals (Appendix I), it was found that all the stress relaxation curves could be fitted by a four element model:

$$1.) \quad S = S_1 e^{-t/\tau_1} + S_2 e^{-t/\tau_2} + S_3 e^{-t/\tau_3} + S_4 e^{-t/\tau_4} \text{ at constant T}$$

In order to shift any stress relaxation curve as a function of temperature, it was then necessary to determine the temperature dependence of the eight constants in equation 1. This procedure is shown in Appendix I and gives the final result:

$$2.) \quad \frac{S}{S_o} = \sum_{j=1}^{4} \left(\frac{\tau_j}{\tau_o}\right)^{\left(\frac{1}{\delta/T - \rho}\right)} e^{-t/\tau_j} \qquad \text{at constant T}$$

where $$\tau_j = \beta e^{\frac{E_j}{2}\left(\frac{1}{T} - \gamma\right)} \qquad \text{at constant T}$$

and S_o is the initial stress, t is the time, T is the absolute temperature and τ_o, δ, ρ, β, γ and the E's are constants.

Very good agreement has been observed thus far between the predicted 73°F stress relaxation curves and the experimental data at that temperature.

For all of the five different thermoplastics the values of E_1, E_2, E_3 and E_4, which correspond to activation energies, decrease from about 30 kilocalories/mole for E_1 to about 1 kilocalorie/mole for E_4. This indicates that each of the relaxation times has a different temperature dependence and

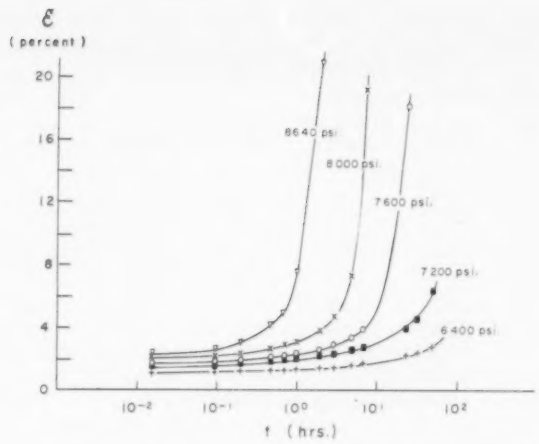


Figure 6. Creep curve for styrene-acrylonitrile polymer—H, 73°F. Data was obtained at five different stress levels.

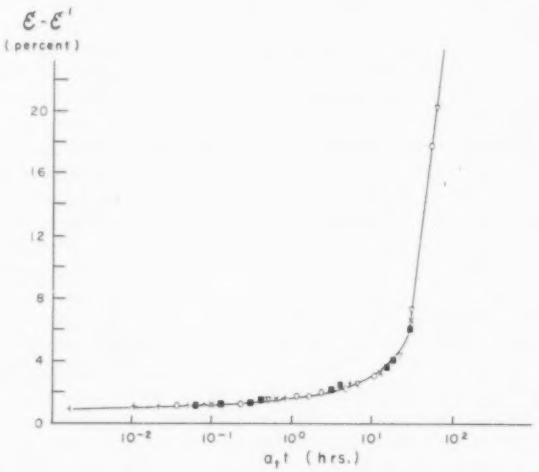


Figure 7. Master curve for styrene-acrylonitrile polymer—H, 73°F. Value E' represents the initial elongation at any stress minus the initial elongation at 6400 psi

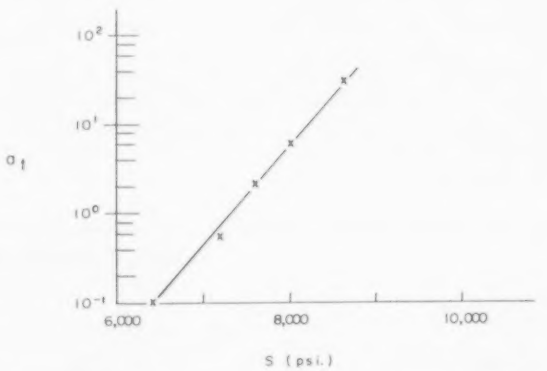


Figure 8. Shift factor vs. stress, for styrene-acrylonitrile polymer—H, 73°F

Table 1. Comparison of Calculated & Experimental Shift Factors for ABS Polymer-B

Temp. (°F)	S (psi)	ϵ (@ t = 1 min.)	ϵ_o (calc.)*	a_t (exper.)	a_t (calc.)*
80	4800	—	1.55	36.8	33.5
80	4400	—	1.42	8.6	8.5
80	4000	1.27	1.29	2.02	2.10
80	3440	1.10	1.11	0.33	0.31
120	2640	1.08	0.85	1.55	1.63
120	2400	0.77	0.78	0.46	0.48
120	2000	0.59	0.65	0.061	0.063
160	1760	0.75	0.57	26.1	25.2
160	1200	0.59	0.39	0.70	0.68
160	800	0.34	0.26	0.052	0.051

* See Table 2 for constants to compute ϵ_o and log a_t.

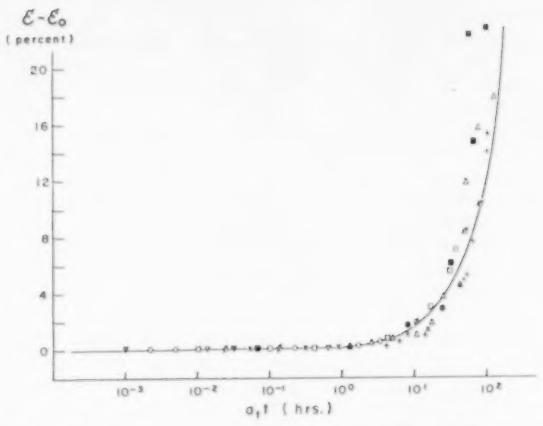


Figure 9. Master creep curve-ABS Polymer-B

shows mathematically that the Tobolsky-Ferry time-temperature shift, which postulates the same temperature dependence of all relaxation times, will not work for these data.

The creep results are shown in *Figures 6-11*. For the sake of clarity many experimental points were omitted in *Figures 9-11*. The method for shifting the data at constant temperature is illustrated by *Figures 6, 7 and 8*. *Figure 6* shows the data obtained at five different stress levels at 73°F for styrene-acrylonitrile polymer-H. To construct the master curve of *Figure 7*, a sheet of graph paper was laid over *Figure 6* so that the point $a_t t = 10^{-1}$ coincided with the point t = 1.0 in *Figure 6*. The points for S = 6400 psi were then traced. The sheet was then shifted horizontally and vertically so the points for S = 7200 psi overlapped those traced for S = 6400 psi. The value of a_t was obtained from the point on the $a_t t$ axis coincident with the value of t = 1.0 in *Figure 6*. Similarly, further shifts bring the points for 7600, 8000 and 8640 psi onto one curve. In *Figure 7*, the value ϵ' represents the initial elongation at any stress minus the initial elongation at 6400 psi. *Figure 8* shows the log of the experimental values of a_t plotted vs. the stress. A least squares fit of these points gives the linear relationship:

$$3.) \qquad \log a_t = 1.125 \times 10^{-4} S - 8.226$$

It should be noted that the initial choice of the position of the sheet onto which *Figure 7* is traced is completely arbitrary. In this work the master curves were constructed so that the elbow of the curve occurred between $a_t t = 10$ and $a_t t = 100$. In this manner master curves at constant temperature are constructed for each of the materials tested at each temperature. The methods for the temperature shift and the creep equation are given in Appendix II. The final result is:

$$4.) \qquad \epsilon - \epsilon_o = 108.62\ (1 - e^{-Bat\,t})$$

where $\epsilon_o = KS$

and $$\log a_t = c\,S - d\,\frac{S}{T} - \frac{k_1(T_s - T)}{k_2 - T_s + T}$$

Table 1 gives a comparison of the calculated and experimental shift factors for acrylonitrile-butadiene-styrene polymer-B. It can be seen that the calculated values of both ϵ_o and a_t are in good agreement with the experimentally determined values.

The master creep curve for ABS polymer-B is given in *Figure 9*. The points have all been shifted using the calculated values for ϵ_o and a_t given in *Table 1*. The line drawn on the curve is given by the equation:

$$5.) \qquad \epsilon - \epsilon_o = 108.62\ (1 - e^{-1.250 \times 10^{-4}\, a_t t})$$

i.e. the value of B in equation 4 is taken as 1.250×10^{-4}.

Master creep curves are also shown for ABS polymer HTHT in *Figure 10* and ABS polymer-L in *Figure 11*. The values for the constants in equation 4 are listed in *Table 2*. From the figures it can be seen that the data are all shifted quite well onto a single master curve and that this curve can be approximated by a single term exponential equation. In addition, the 1000 hour test data which are not shown here fit these curves very well using the calculated shift factors. Thus, knowing three of the four quantities, stress, elongation, time and temperature, we can compute the fourth either by a graphical or strictly mathematical procedure. In addition, creep curves can be constructed for any given stress and temperature.

At the present time the exact limitations of these equations in terms of stress and temperature are not known. It is expected that they would be valid within the temperature range of the experiments, 73 to 160°F for ABS polymer-B and ABS polymer-L and 73 to 200°F for ABS

Table 2. Constants for Master Creep Curves

Material	$K \times 10^4$	B	$c \times 10^5$	d	k_1	k_2	T_s
ABS polymer-B	3.23	1.250×10^{-4}	1.161	3.031	—5.8007	—0.92	345.92
ABS polymer-HTHT	2.62	1.111×10^{-4}	.7131	1.492	—14.891	—26.35	374.09
ABS polymer-L	3.02	3.333×10^{-4}	.7569	1.288	1.7049	341.94	585.42

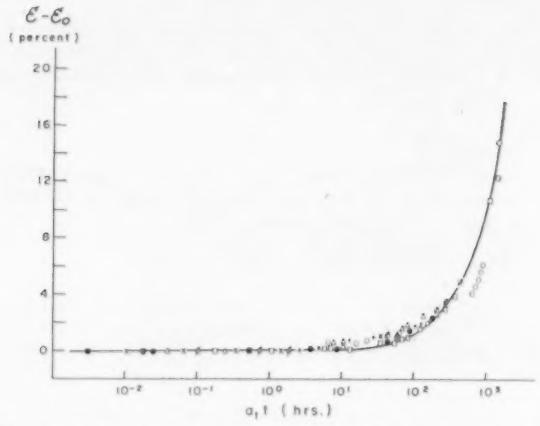


Figure 10. Master creep curve-ABS polymer-HTHT

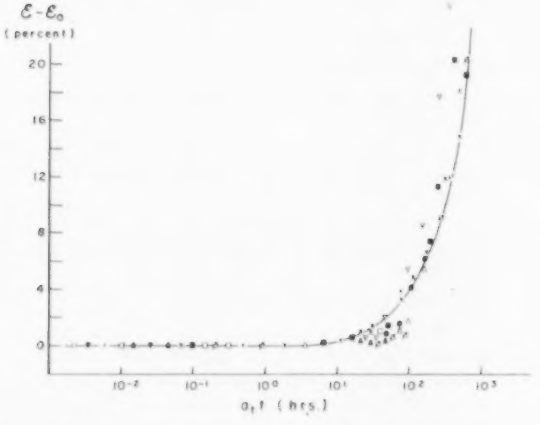


Figure 11. Master creep curve-ABS Polymer-L

polymer HTHT. The stress dependence of the shift factor is thought to be quite unusual. The only similar effect which has come to our attention is the reported strain dependence of the shift factor in stress relaxation experiments (4). It is felt that if the linear dependence of log a_t on S did not hold at very low stresses, the straight line would curve downward thus making our long term predictions more conservative.

Conclusions

By using appropriate analytical expressions, it has been possible to perform a time-temperature shift of our stress relaxation data. This enables us to run short term, high temperature tests to predict long term room temperature performance. Agreement between experimental and predicted room temperature data has been good for those samples where this check was carried out. Similarly, long term creep data can be obtained by a stress and/or temperature-time shift of relatively short term data. Once again there has been good agreement between predicted and experimental long term results. At present, these extrapolations are valid to at least 10,000 hours and further work is being done to extend this limit.

It was originally hoped that this work would also lead to a simple method for converting stress relaxation to creep data. Although this has been attempted by MacLeod (5) and by Knowles and Dietz (10), their methods have been restricted to rather narrow time intervals, Our results indicate that a simple interconversion of the data is not possible. The creep data are represented by an isolated spring in series with a Voigt element (a spring and dashpot in parallel) while a much more complicated model is necessary to fit the stress relaxation data. The simple creep model may be due to the fact that the curves that are shifted together represent too narrow a time interval. However, longer term data have not shown any significant change in the shape of the creep curve. A more important difference between the two tests is the following: In the creep tests at high elongations the density of the samples decreases in the elongated section (for this reason one cannot make a simple correction to the data to compensate for the increased stress as the cross sectional area of the sample decreases), while in the stress relaxation tests no such density change occurs as the stress relaxes to zero. This difference in physical behavior indicates that there may be different failure mechanisms operating in each case. If this is true, there will be no correspondence between the creep and stress relaxation tests. However, this point needs further investigation at this time.

We have had considerably greater success in correlating the creep data for ABS polymer-B and ABS polymer-HTHT with long term pipe stress-rupture data. Using Eyring's reaction rate theory (11) as developed by Coleman (12) for creep failure of polymeric filaments, an excellent correlation has been found between t_{16}, the time to 16% elongation in creep tests, and t_B, the time to break in pipe failure tests.

The authors would like to acknowledge the assistance of George F. Schrappel and Margaret Twelves who obtained the stress relaxation and creep data, respectively.

Appendix I

Treatment of Stress Relaxation Data to Compute Temperature Shift

The data at any temperature are plotted as log stress vs. time yielding an exponential decay curve. This curve tends to become linear at large values of t. The linear portion is extrapolated back to t = 0. This extrapolation yields S_1 (from the intercept) and $1/\tau_1$ (from the slope). A second plot of log $(S - S_1)$ vs. t is made and the above procedure is repeated yielding S_2 and $1/\tau_2$. Next, log $(S - S_1 - S_2)$ is plotted vs. t giving S_3 and $1/\tau_3$ and finally a plot of log $(S - S_1 - S_2 - S_3)$ vs. t (which is linear) gives values for S_4 and $1/\tau_4$. This procedure is carried out at three temperatures giving three equations containing a total of 24 constants.

1a) at T_1 $S_{T_1} = S_{11}e^{-t/\tau_{11}} + S_{12}e^{-t/\tau_{12}} + S_{13}e^{-t/\tau_{13}} + S_{14}e^{-t/\tau_{14}}$

1b) at T_2 $S_{T_2} = S_{21}e^{-t/\tau_{21}} + S_{22}e^{-t/\tau_{22}} + S_{23}e^{-t/\tau_{23}} + S_{24}e^{-t/\tau_{24}}$

1c) at T_3 $S = S_{31}e^{-t/\tau_{31}} + S_{32}e^{-t/\tau_{32}} + S_{33}e^{-t/\tau_{33}} + S_{34}e^{-t/\tau_{34}}$

These equations can be written in general form as:

1d) $S_i = \sum_{ij} S_{ij}e^{-t/\tau_{ij}}$ $(i = T_1, T_2, T_3; j = 1, 2, 3, 4)$

In order to compute the shift of the stress relaxation curves as a function of temperature, it is necessary to determine the temperature dependence of the S_{ij}'s and τ_{ij}'s. It was found that plots of log τ_{ij} vs. 1/T were linear indicating

2) $$\tau_j = C_j\, e^{E_j/RT}$$

In addition, the lines for the four values of j could be extended to intersect at a single point $(1/T = \gamma)$ giving

3) $$\tau_j = e^{\left[\frac{E_j}{2}\left(\frac{1}{T} - \gamma\right)\right]}$$

where E_j is the activation energy, the value of the gas constant R, is taken as 2 and β and γ are constants.

Spectral distribution plots were made of Sj as a function of τ_j. These plots gave linear relationships between log S_j/S_o and log τ_j at the three temperatures with a common intercept at $\tau_j = \tau_o$.

4) $$S_j/S_o = (\tau_j/\tau_o)^{1/q_t}$$

where $S_o = S_1 + S_2 + S_3 + S_4$ at any temperature and $q_t = f(T)$

Finally it was found that:

5) $$q = \delta/T - \rho$$

giving the result

6) $$\left(\frac{S_{tj}}{S_o}\right) e^{-t/\tau_{tj}} = \left\{\frac{\beta e^{E_j/2\left(\frac{1}{T_t} - \gamma\right)}}{\tau_o}\right\}^{\left(\frac{1}{S/T_t - \rho}\right)} \times e^{-\left(\frac{t}{\beta e^{E_j/2\,(1/T_t - \gamma)}}\right)}$$

Using values of E_j, T_t and $t = 0$ values were calculated for:

7) $$(S/S_o) = (S_1/S_o) + (S_2/S_o) + (S_3/S_o + (S_4/S_o) = 1.00$$

or

7a) $$\left(\frac{S}{S_o}\right) = \sum_{j=1}^{4} \left\{\frac{\beta e^{E_j/2\left(\frac{1}{T} - \gamma\right)}}{\tau_o}\right\}^{\left(\frac{1}{S/T - \rho}\right)}$$

If the sum departed more than a few points from 1.00, the constants δ and ρ were adjusted slightly to bring the sum closer to 1.00, usually between 1.02 and 0.95.

Appendix II

Load-Temperature Shifts for Creep Curves

At constant temperature the logarithm of the shift factor was found to be linearly related to the applied stress:

1) $$\log a_t = a\,S - b$$

where a and b are both temperature dependent constants.

It was found that the value of a in equation 1 was proportional to the reciprocal of the absolute temperature:

2) $$a = c - d/T$$

It was not possible to obtain a linear relationship between b and either T or 1/T. Therefore, an equation of the form of the Williams-Landel-Ferry relation (8) was used:

3) $$b = \frac{k_1\,(T_s - T)}{k_2 - T_s + T}$$

This could be empirically fitted to the data.

Since in the temperature region of these tests, the elastic modulus is not expected to change very rapidly, the initial elastic response could be represented with sufficient accuracy by:

4) $$\epsilon_o = KS$$

Finally, because all the creep curves had approximately the same shape, it was felt that they could all be fitted by a single exponential equation of the form:

5) $$\epsilon - \epsilon_o = A\,(1 - e^{-\beta t})$$

By using a value of A = 108.62 and taking $\beta = BA_t$ where B is a constant for each material, all the curves could be fitted except at the highest elongations. The final result is then:

6) $$\epsilon - \epsilon_o = 108.62\,(1 - e^{-BA_t t})$$

where $\epsilon_o = KS$

and $$\log a_t = c\,S - d\,S/T - \frac{k_1\,(T_s - T)}{k_2 - T_s + T}$$

Literature References

1. A. V. Tobolsky and R. D. Andrews, *J. Chem. Phys. 11*, 125 (1943).
2. H. Leaderman, "Elastic & Creep Properties of Filamentous Materials," The Textile Foundation, Inc., Washington, D. C. (1943).
3. A. V. Tobolsky, *J. Appl. Phys. 27*, 673 (1956).
4. E. Passaglia and H. P. Koppehele, *J. Polymer Sci. 33*, 281 (1958).
5. A. A. MacLeod, *Ind. Eng. Chem. 47* (No. 7), 1319 (1955).
6. B. Maxwell, *J. Polymer Sci. 20*, 551 (1956).
7. J. D. Ferry, E. R. Fitzgerald, L. D. Grandine, Jr. and M. L. Williams, *Ind. Eng. Chem. 44* (No. 4), 703 (1952).
8. M. L. Williams, R. F. Landel & J. D. Ferry, *J. Am. Chem. Soc. 77*, 3701 (1955).
9. T. Alfrey, Jr., "Mechanical Behavior of High Polymers," Interscience, New York (1948).
10. J. K. Knowles and A. G. H. Dietz, "Viscoelasticity of Polymethylmethacrylate—An Experimental & Analytical Study," *Trans. A.S.M.E.* (February 1955).
11. S. Glasstone, K. J. Laidler and H. Eyring, "The Theory of Rate Processes," McGraw-Hill, New York (1941).
12. B. D. Coleman, *J. Polymer Sci. 20*, 447 (1956).

Next Month

NEW STRESS CRACKING TEST

A new procedure for evaluating environmental stress cracking properties of polyethylene will be published in next month's issue of the SPE Journal. The method makes provision for a constant stress to be applied to test specimens. The test can be used to evaluate polyethylene of any density or degree of flexibility.

The Effect of an Amine Cured Epoxy Resin on the Stability of Trinitrotoluene

Mechanisms of cure of an epoxy resin with four different amine curing agents

Hugh C. Anderson
U.S. Naval Ordnance Laboratory
White Oak, Silver Spring, Maryland

It is sometimes necessary to use adhesives and reinforced plastics in contact with explosives. The usual superior properties of amine-cured epoxy resins would ordinarily make them desirable candidates for such applications. However, it has been found that these materials generally cause explosives to undergo slow decomposition (incompatibiltiy). Certain amine-cured epoxy resins may be compatible while others may be incompatible with a given explosive. Some of the factors which evidently contribute to this situation are type and basicity of the amine, mechanism of cure, and structure of the cured resin. On the other hand, some explosives may be compatible while others may be incompatible with a given amine-epoxy resin system. The controlling factors here are probably the structure of the explosive and the extent to which oxidation-reduction potentials occur between the amino groups of the resin system and the nitro groups of the explosive. The purpose of the work described herein was to determine how a typical epoxy resin cured with various amines would affect the stability of trinitrotoluene (TNT), a typical explosive.

Most commercial epoxy resins may be represented by formula (1) in *Figure 1*, where n may vary from zero to about nine. The resin used in our experiments had an n value of approximately zero. Since the epoxy groups are the principal reactive centers in Epon 828, ethylene oxide may be used to demonstrate some of its reactions.

As seen in equation (2), *Figure 1*, etherification may occur through two epoxy groups. Equation (3) shows that the epoxy group can be etherified with an alcohol. Reactions (2) and (3) are catalyzed by basic substances such as tertiary amines and acidic substances such as borontrifluoride. The epoxy group may also react with primary and secondary amines, as shown in equation (4). The secondary amino group resulting from the reaction of a primary amine with the epoxy group can further react with an epoxy group to form a tertiary amine. Most analytical procedures for the quantitative determination of epoxy groups are based on the reaction shown in equation (5) employing suitable solvents.

Epoxy resins have very desirable strength and heat resistance properties because of their crosslinking potentialities. There are at least two postulated ways by which epoxy resins can be crosslinked. Since these resins contain two epoxy groups (each epoxy group having a functionality of two), crosslinking can occur by utilization of epoxy groups only with a suitable catalyst which activates the resonating structures, as shown in equation (1), *Figure 2*. Crosslinking can also occur by the reaction of two epoxy groups with a diamine, as shown in equation (2). The tertiary amino group in diethylaminopropylamine can catalyze etherification type crosslinking while the other polyamines, which have more than one primary amino group, can effect crosslinking by coreaction with epoxy groups.

Experimental Work

A. Resin Systems

Shell's Epon 828, a typical commercial epoxy resin, was cured for 24 hours at 25°C, plus 24 hours at 65°C with

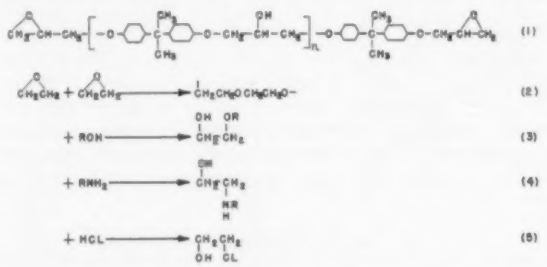
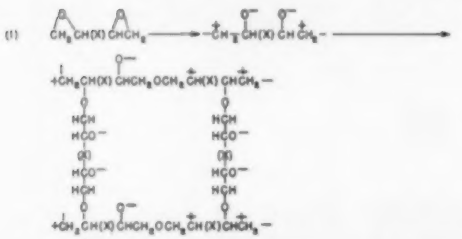


Figure 1. Typical epoxy resin and reactions of the epoxy group

CROSSLINKING THROUGH EPOXY GROUPS



WHERE (X) REPRESENTS THE REMAINING PORTION OF THE EPOXY RESIN MOLECULE.

CROSSLINKING THROUGH AMINO GROUPS

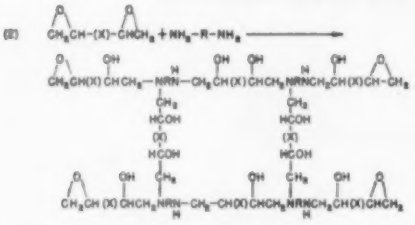


Figure 2. Crosslinking reactions

various amounts of diethylaminopropylamine, 1,6-hexanediamine, diethylenetriamine and meta-phenylenediamine.

B. Percentage Epoxy Conversion

The percentage epoxy conversion was determined as described in reference (1). Briefly, this consisted of pulverizing the cured products to a very fine powder and reacting a known weight of the powder with a known aliquot of 0.2 normal hydrochloric acid-dioxane reagent. At the end of the analytical reaction, the unreacted hydrochloric acid was titrated with 0.1 normal silver nitrate solution using an automatic titrimeter. The difference between a blank titer and the sample titer was equal to the amount of hydrochloric acid consumed by the residual epoxy groups. The precision was better than ±2% for duplicate determinations.

C. Percentage Apparent Swelling and Deformation-Under-Load

Percentage apparent swelling which is considered to be a measure of the degree of crosslinking (reference (2)) was determined as follows: A small glass cylinder containing a solution of 95 mole per cent of 1,2-dichloroethane and 5 mole per cent of n-hexadecane was placed in the bottom of a vacuum desiccator. Approximately 0.5 gm of the fine plastic powder was accurately weighed into a 25 ml ground glass stoppered Erlenmeyer flask. The stopper was removed, and the flask placed in the desiccator. The desiccator was then covered, quickly evacuated to a pressure of about 10mm, and closed off from the vacuum pump. The ethylene chloride then vaporized and was allowed to remain in contact with the powder for at least 24 hours at 25°C, or until equilibrium was reached. The flask containing the powered sample was removed from the desiccator, stoppered and reweighed. The percentage apparent swelling (%S) was calculated as follows:

$$\%S = \frac{\text{wt. 1,2-dichloroethane absorbed by powder}}{\text{wt. powder}} \times 100$$

Precision was better than ±2% for duplicate determinations.

Percentage deformation-under-load determinations, also considered a measure of crosslinking, consisted of machining one-half inch cylinders from a cast sample and testing the cylinders according to ASTM D-621-51.

D. Vacuum Stability Test

The explosive stability (compatibility) data were obtained in the following manner: 0.2 gm of pulverized (40-60 mesh) plastic was intimately mixed with 0.2 gm of the TNT, introduced into a vacuum system at 100°C, and at the end of 48 hours the number of cc of gas evolved was measured with a manometer and corrected to standard conditions. The results are reported as cc of gas per gram of TNT. The capacity of the apparatus was approximately 15 cc. The net evolution of not more than 2 cc of gas was considered to indicate compatibility.

Results and Discussion

A. Epoxy Conversion versus Amount of Curing Agent

Figure 3 shows that when only a 25% stoichiometric amount (SA) of diethylaminopropylamine was reacted with Epon 828, about 95% of the epoxy groups were consumed. This seems to indicate that the primary amino group of the amine coreacted with the epoxy group. Further reaction then occurred by etherification of the remaining epoxy groups themselves and by etherification of epoxy groups with the alcoholic groups which were generated by the reaction of the primary amino group of the curing agent with epoxy groups. Since the reaction of amino hydrogens with epoxy groups is much faster than the etherification reactions (3), it can be assumed that 25% of the epoxy conversion was due to the amino hydrogens. This leaves about 70% of

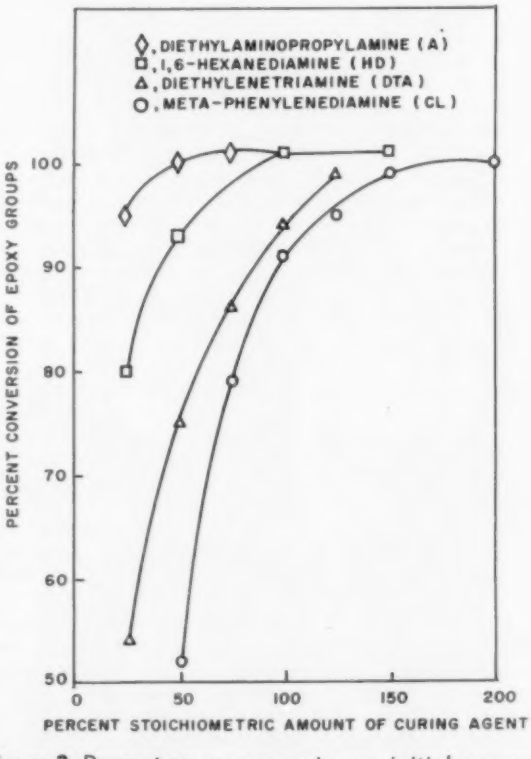


Figure 3. Percent epoxy conversion vs. initial concentration of curing agent

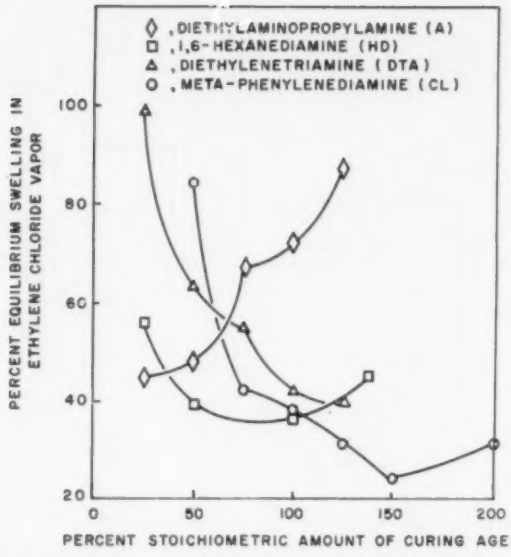


Figure 4. Percent swelling versus initial concentration of curing agent

the consumed epoxy groups unaccounted for. Since the reaction of hydroxy groups with epoxy groups is faster than epoxy etherification (4), it is possible that they were consumed by 25% of the remaining epoxy groups. This would leave about 45% of the epoxy groups for etherification among themselves. The above reactions undoubtedly compete to some extent.

In the case where 50% and 75% SA of diethylaminopropylamine were used and all of the epoxy groups were consumed, the number of epoxy groups which react by etherification is believed to be about 50% and 25% respectively. This belief seems logical in view of the relative reaction rates mentioned above. However, further support for this belief will be offered in the discussion of the apparent swelling data. Greater than a 75% SA of diethylaminopropylamine caused the resulting cured resin to be too thermoplastic to be handled in the analytical procedure.

It is also seen in *Figure 3* that when a 25% SA of 1,6-hexanediamine was reacted with Epon 828, about 80% of the epoxy groups disappeared. Making the rough assumption that all of the amino hydrogens reacted, about 55% of the consumed epoxy groups would have to be accounted for otherwise. Therefore, it appears that the tertiary amino groups produced in the course of the reaction catalyzed etherification of the remaining 55% of epoxy groups. It is interesting to compare the behavior of this amine with that of diethylaminopropylamine. The latter already had a tertiary amino group and was, therefore, more effective in catalyzing etherification than the more bulky tertiary amine formed by 1,6-hexanediamine. In the case of the 1,6-hexanediamine, crosslinking occurs by both etherification and by amino coreaction as opposed to only etherification crosslinking with diethylaminopropylamine.. This will become clearer in the discussion of the apparent swelling data.

As shown in *Figure 3*, diethylenetriamine, which contains two primary and one secondary amino groups, presents still another picture. When Epon 828 is cured with a 25% SA of this amine, only about 54% of the epoxy groups are consumed. If all of the amino hydrogens were reacted, the remaining 29% of consumed epoxy groups would have to be accounted for by etherification. Neither 1,6-hexanediamine nor diethylenetriamine had tertiary amino groups in the beginning, but were dependent upon tertiary amino groups being generated in the course of the reaction for catalyzing etherification of any epoxy groups. The probable reason for 1,6-hexanediamine being more effective in conversion of the epoxy groups than diethylenetriamine is that the reactive amino groups in the former are separated by six carbon atoms while the latter is separated by only two carbon atoms; consequently, steric hindrance comes into play in these respective generated tertiary amines for catalysis of the etherification reactions.

Figure 3 also shows how polymerization of the epoxy group has progressed from a predominantly etherification type of reaction with diethylaminopropylamine and the other two amines to a predominantly coreaction of amino and epoxy groups with meta-phenylenediamine. A 50% SA of meta-phenylenediamine consumed only about 52% of the epoxy groups, and a 75% SA consumed about 78%. The apparent reason for this difference is that the tertiary amine produced by reaction of the aromatic amino groups with epoxy groups is too sterically hindered to catalyze any etherification. The differences in basicity may also be a contributing factor, aromatic amines being much less basic than aliphatic amines.

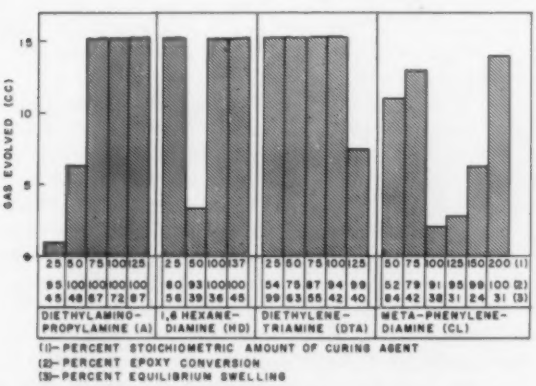


Figure 5. Explosive compatibility vs. curing agent, epoxy conversion and swelling

B. Apparent Swelling versus Amount of Curing Agent

Figure 4 shows that the percentage apparent swelling increases (decrease in degree of crosslinking) with amount of diethylaminopropylamine used. This is in harmony with the epoxy conversion results and the kinetics of the reactions concerned. Crosslinking could not take place through the amino group because only one of the amino groups contained hydrogen. At least two primary or one primary and one secondary amino groups in an amine are required for this type of crosslinking. However, since the epoxy resin had a functionality of four, etherification crosslinking could occur. Therefore, as the increased amount of diethylaminopropylamine used led to more linear polymerization, the number of epoxy groups left for etherification crosslinking decreased because the former reaction is much faster than the latter one. This line of reasoning will be further substantiated in a discussion of the explosive compatibility results.

Figure 4 also shows that for the other three amines, which have a sufficient number of primary amino groups for amino crosslinking, the percentage swelling decreases through a minimum (the degree of crosslinking increasing through a

maximum) with increasing amounts of curing agent. It must be pointed out here that degree of swelling can only be taken as a measure of the degree of crosslinking for one given amine-epoxy system and not as a measure of the differences in degree of crosslinking for different amine-epoxy systems. For example, in referring to *Figure 4*, it can be assumed that the system employing a 100% SA of meta-phenylenediamine is more highly crosslinked than the system employing a 50% stoichiometric amount. However, on the other hand, it cannot be assumed that the degree of crosslinking of the 1,6-hexanediamine-epoxy and meta-phenylenediamine-epoxy systems are equal at a 100% stoichiometric amount of curing agent just because the respective degrees of swelling are about equal. This is because structural and solubility parameters are different for different systems with a given swelling agent.

C. Compatibility of Cured Resin with Trinitrotoluene

Examination of *Figure 5*, a bar graph showing explosive compatibility in relationship to % SA of curing agent, % epoxy conversion, and % apparent swelling, leads to some interesting observations. First of all, it is very interesting to note that Epon 828 cured with a 25% stoichiometric of diethylaminopropylamine is compatible with TNT. Since this amine in the pure state is incompatible with TNT, compatibility of the resulting cured amine-epoxy system may be explained as follows: All of the hydrogens of the primary amino group probably reacted with epoxy groups, as pointed out in a previous section of this report. Then, the resulting linear polymer containing epoxy and two tertiary amino groups probably crosslinked by epoxy etherification. The solubility of this crosslinked material in the TNT was probably low enough to permit virtually no interaction between the amino and nitro groups. However, on the other hand, where the degree of crosslinking began to decrease for increasing amounts of diethylaminopropylamine, as indicated by increase in swelling, explosive incompatibility resulted. Evidently, the ratio of linear polymerization to crosslinking polymerization, as discussed in a previous section, resulted in sufficient solubility to permit interaction of the amino and nitro groups.

Figure 5 shows the contrasting behavior of meta-phenylenediamine and diethylaminopropylamine with regard to explosive compatibility. Epon 828 cured with either a 100% SA of the former or 25% SA of the latter was compatible with TNT. This difference in behavior is readily explainable in light of the different mechanisms discussed earlier. In the case of diethylaminopropylamine, epoxy etherification as well as coreaction of the primary amino group with epoxy groups occurred while polymerization involving meta-phenylenediamine was principally coreaction of the amino groups with epoxy groups.

It is noted in *Figure 5* that % swelling is equal (31%) for two different amounts (125% and 200% SA) of meta-phenylenediamine, while the corresponding compatibility values were 2.7 and 14.2 cc. The reason offered for this observation is as follows: For the swelling determinations, the fine electrostatically charged powders were separated from the milling balls (reference (2)) with alcohol. Since the equal swelling values indicate the same degree of crosslinking, excess of amine curing agent in the 200% SA specimens was probably extracted by the alcohol wash. However, the explosive compatibility samples were not treated with alcohol and the unreacted amine in the 200% SA specimen resulted in a higher evolution of gas than the 125% SA specimen where less excess amine was present.

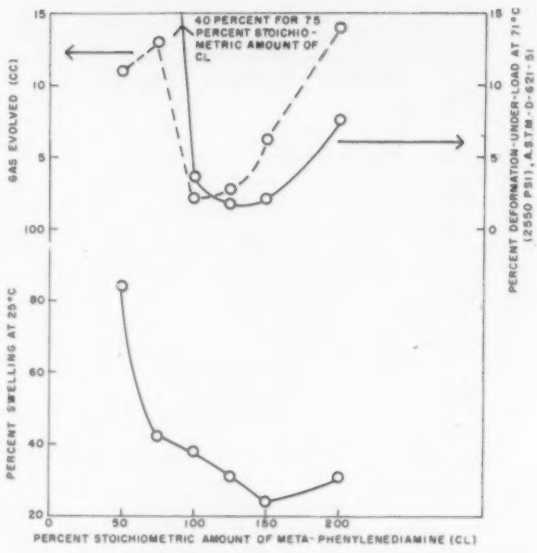

40 PERCENT FOR 75 PERCENT STOICHIOMETRIC AMOUNT OF CL
GAS EVOLVED (CC)
PERCENT SWELLING AT 25°C
PERCENT DEFORMATION-UNDER-LOAD AT 71°C (2550 PSI), A.S.T.M.-D-621-51
PERCENT STOICHIOMETRIC AMOUNT OF META-PHENYLENEDIAMINE (CL)

Figure 6. Comparison of explosive compatibility data with swelling and deformation-under-load-data

The reason given for the above observation is further established by examining *Figure 6*. When deformation-under-load is measured as a function of the amount of meta-phenylenediamine used, the dimensional changes are not equal for the 125% and 200% SA systems. In fact, the dimensional change for the 200% SA system was greater than that for the 125% SA one, as would be expected. The test specimens were not subjected to treatment with alcohol and consequent dissolution of residual amine.

In *Figure 6* it is seen that there is closer correlation between compatibility and deformation-under-load than between compatibility and swelling. When compatibility or deformation-under-load was plotted against % SA of amine, both curves went through a minimum (maximum crosslinking) in about the same region. The plasticity on the left side of the minimum is probably due to unreacted epoxy groups, while on the right side it is probably due to a more open network structure or unreacted amino groups. It would be expected that the amino hydrogens would be more completely reacted when a 50% SA of meta-phenylenediamine is used than when a 100% SA is used, and that the former would result in greater compatibility. However, the converse was found. One explanation of this is that even though all of the amine in the 50% mixture was probably reacted, the plasticity was great enough to allow solubility in the TNT and subsequent reaction.

It has been found that aniline is compatible with trinitrotoluene while meta-phenylenediamine is not. In fact, aniline actually forms a stable molecular complex with trinitrotoluene (reference (5)). Since these two amines are about equal in basicity, the difference in compatibility is probably due to the presence of two amino groups in meta-phenylenediamine. Evidently, two amino groups on the aromatic nucleus are more conducive than one to the establishment of oxidation-reduction potentials between the nitro and amino groups.

Examination of *Figure 7* leads to some interesting observations. It is noted that samples resulting from the use of 75%, 100% and 125% stoichiometric amounts of diethylaminopropylamine were very incompatible with TNT. The

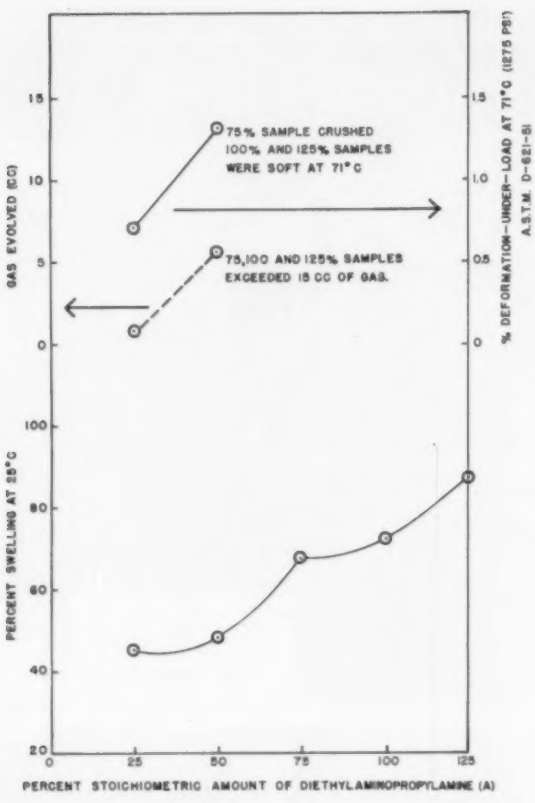

75% SAMPLE CRUSHED
100% AND 125% SAMPLES
WERE SOFT AT 71°C
75,100 AND 125% SAMPLES
EXCEEDED 15 CC OF GAS.
GAS EVOLVED (CC)
% DEFORMATION-UNDER-LOAD AT 71°C (1275 PSI)
A.S.T.M. D-621-51
PERCENT SWELLING AT 25°C
PERCENT STOICHIOMETRIC AMOUNT OF DIETHYLAMINOPROPYLAMINE (A)

Figure 7. Comparison of explosive compatibility data with swelling and deformation-under-load-data

corresponding deformation-under-load properties were also very poor; the 75% sample crushed, and the 100% and 125% samples were too soft for the test. The corresponding swelling values are also high. For the 25% and 50% samples, deformation-under-load and swelling values are seen to increase with cc of gas evolved (a measure of compatibility). Comparison of these data with those for the meta-phenylenediamine-epoxy resin systems gives further support for the different mechanisms of cure mentioned earlier in this paper. In the case of the diethylaminopropylamine, the ratio of linear to crosslinked polymer increases with amount of curing agent used and results in materials of inferior properties above a 25% stoichiometric amount. It is seen in Figure 6 that when meta-phenylenediamine is used, the properties go through a minimum with increasing amounts of curing agent. This difference in behavior for the two amines is due to the following two facts: (a) diethylaminopropylamine is involved in etherification crosslinking and linear reaction of the primary amino hydrogens with the epoxy group, and (b) meta-phenylenediamine is involved only in coreaction with the epoxy groups.

Summary

An epoxy resin was polymerized with various amounts of four different amine curing agents. The following tests were made on the resulting products: (a) percentage epoxy conversion, (b) percentage swelling, (c) compatibility with trinitrotoluene, and (d) percentage deformation-under-load.

The following observations were made:

a. Percentage epoxy conversion increased with amount of each curing agent used. Diethylaminopropylamine was the most efficient in converting the epoxy groups and meta-phenylenediamine was the least efficient. These results are in harmony with the chemistry of the reactions involved.

b. Percentage swelling decreased through a minimum with amount of curing agent used for 1,6-hexanediamine, diethylenetriamine and meta-phenylenediamine and increased for diethylaminopropylamine. These results are also in harmony with the chemistry of the reactions involved.

c. The epoxy resin cured with a 25% stoichiometric amount of diethylaminopropylamine or a 100% stoichiometric amount of meta-phenylenediamine was compatible with TNT.

d. Deformation-under-load measurements were made using diethylaminopropylamine and meta-phenylenediamine and were found to correlate with explosive compatibility data.

Acknowledgment

The author wishes to express his appreciation to the Organic Chemistry Division for performing the vacuum stability tests.

This paper was presented at the 143rd National Meeting of the American Chemical Society, Chicago, September 1958.

Literature References

(1) Anderson, H. C., *Plastics Technology 5*, 40 (1959).

(2) Dannenberg, H., and Harp, W. R., *Anal. Chem. 28*, 86 (1956).

(3) Shechter, L., and Wynstra, J., and Kurkjy, R. P., *Ind. Eng. Chem.* 48, 94 (1956).

(4) Shechter, L., and Wynstra, J., *Ind. Eng. Chem. 48*, 86 (1956).

(5) Davis T. C., 1951. *The Chemistry of Powder and Explosives*, New York: J. Wiley and Sons, Inc.

Plan to attend the

17th ANTEC

January 24-27, 1961

Washington, D. C.

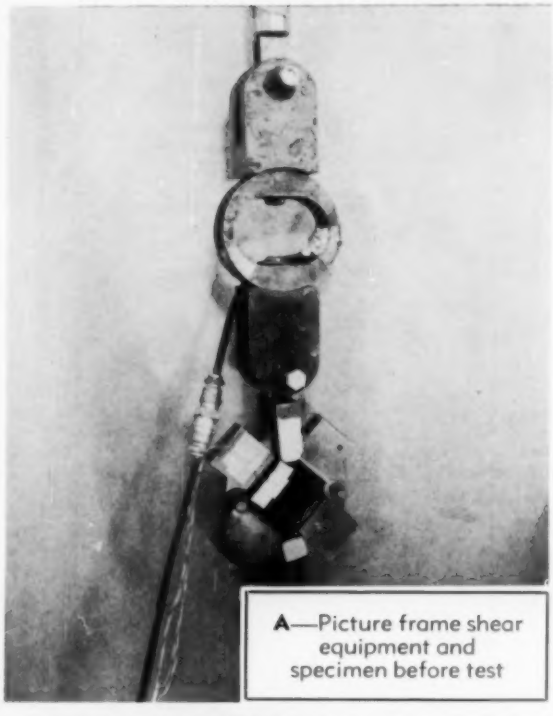
FOR COMPLETE INFORMATION AND RESERVATION FORM SEE PAGE 1179.

A New Device for Determining Shear Properties of Reinforced Plastics

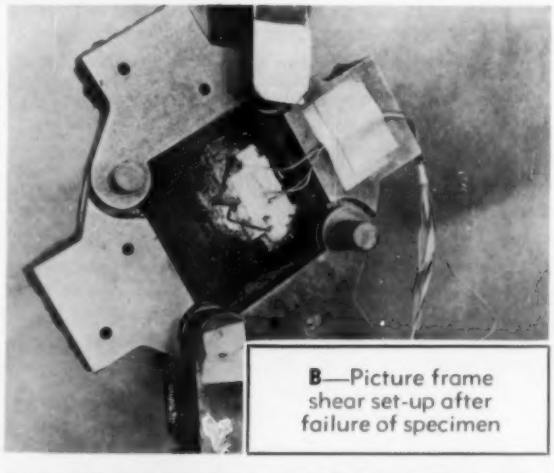
Picture frame loading device makes shear-stress design information easily obtainable

A. P. Penton

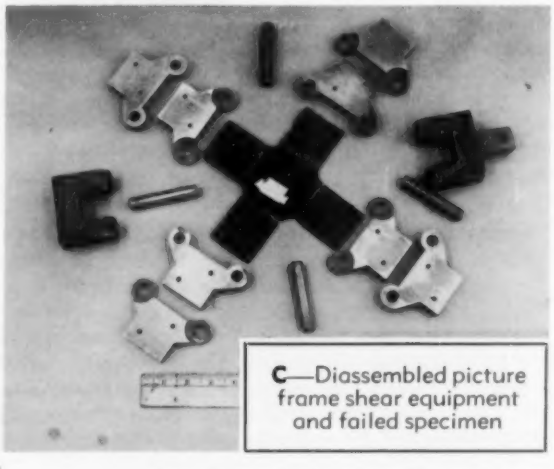
Convair, Division of General Dynamics Corporation



A—Picture frame shear equipment and specimen before test



B—Picture frame shear set-up after failure of specimen



C—Diassembled picture frame shear equipment and failed specimen

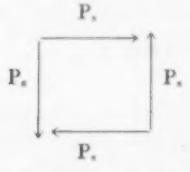
Currently, in the use of laminated glass reinforced plastics for shear resistant structures, the lack of design information for these materials subjected to shear stresses greatly reduces their efficient application. The principal method discussed in this article for determining the shear properties of glass reinforced plastic laminates is a picture frame loading device capable of producing approximately pure edgewise shear forces in the plane of the laminate. Another method, not discussed in this article, uses the Forest Products Laboratory equations (1) to calculate shear from experimentally determined directional properties in tension or compression.

For a glass reinforced plastic laminate to be shear resistant it must not have a tendency to buckle. This may be accomplished by making the laminate thick enough, in relation to its size, so that it will resist buckling; or in the case of honeycomb sandwich with relatively thin laminate faces, the honeycomb core may restrain the faces from buckling. For this article, all tests were performed on laminates which were thick enough to be shear resistant or non-buckling. All tests as described were performed on twelve (12) ply, 181 style, glass fabric reinforced phenolic resin laminates. These laminates were parallel laminated and vacuum bag cured.

THE PICTURE FRAME METHOD

The glass reinforced plastic laminate specimens were milled to the shape as shown by photo C, approximately that of a cross. The flanges of the cross were then bonded between the opposite faces of the picture frame device with an epoxy-phenolic glass fabric reinforced film adhesive. For alignment during the bonding press operation, pins were used in each of the four corners of the frame and in each of the holes in the plates on the sides of the frame. After failure of a specimen the pieces of the metal picture frame were removed from the specimen and acid cleaned before bonding to another specimen.

As seen by *Photo A*, a tensile load is applied to the picture frame through two opposite corner pins. This load is transferred to the specimen through the bond line between the frame and the specimen. The resulting forces on the square exposed center portion of the specimen are applied shear around the perimeter of this square. Since these forces are analytically equal as applied to the exposed portion of the specimen, they resemble the classical pattern for applied pure shear, as given below:



P_s = applied shear forces (the same on all sides)

Since the edgewise shear forces (P_s) on the exposed part of the specimen are at 45° to the tensile force (P) applied to the frame, the relationship between the shear forces and the tensile force applied to the frame is as follows:

$$P_s = P(\cos\ 45°)$$

At failure the ultimate shear strength of the specimen can be calculated from the ultimate tensile force (P_u) as recorded. This calculation is as follows:

$$\text{Ultimate Shear Strength} = P_u(\cos\ 45°)/t_s\ (L_s)$$

Where $t_s(L_s)$ is the shear cross-sectional area of a flange of the specimen.

Shearing strain was measured by two axial strain gages bonded at 90° to each other on one face of the specimen, as shown in *Photo B*. The load applied to the frame (P) was measured by the calibrated steel load ring as shown in *Photo A* and plotted autographically versus shear strain. The graphs resulting from this procedure contain an initial constant slope and related proportional limit. These constant slopes, in pounds per inch, were then used to calculate modulus of rigidity for the specimens as follows:

$$\text{Modulus of Rigidity} = (\text{Value of constant slope})\ (\cos\ 45°)/t_s(L_s)$$

Ultimate shear strength and modulus of rigidity determinations by the picture frame method were performed on two sets of specimens. In the first set, the specimens were cut so that the warp direction of the laminate was at 0° and 90° to the direction of the edgewise shear stresses. In the second set, the specimens were cut so that the warp direction of the laminate was at 45° to the direction of the edgewise shear stresses. The results from the tests on these specimens are reported in the *Table*. As can be seen, the results are reasonably consistent for the specimens with the warp direction at 0° and 90° to the direction of the edgewise shear stresses. A pure edgewise shear failure was not obtained with the specimens with warp direction at 45° to the direction of the edgewise shear stresses. The failure for specimens of this type was by delamination of the first ply in the area under the frame. Because the most efficient fiber orientation is in the 45° specimens, the ultimate edgewise shear strengths of these specimens was not reached before the ultimate interlaminar strength was exceeded. The data reported in the *Table* are for typical specimens. More than one specimen was tested at 45°, but because the interlaminar failures rendered the data useless, only one typical result was reported.

Results of Picture Frame Edgewise Shear Tests*

Angle of Warp to Shear Stresses	Ultimate Shear Strength X10^{-3} PSI	Modulus of Rigidity X10^{-6} PSI	Type of Failure
0°, 90°	$F_{\alpha\beta}$ = 19.3	$G_{\alpha\beta}$ = 1.19	Shear
0°, 90°	$F_{\alpha\beta}$ = 18.1	$G_{\alpha\beta}$ = 1.34	Shear
0°, 90°	$F_{\alpha\beta}$ = 19.5	$G_{\alpha\beta}$ = 1.21	Shear
45°	F_{xy} = 21.3	G_{xy} = 2.03	Interlaminar

* All values are for room temperature tests.

Symbols

$F_{\alpha\beta}$ = ultimate shear strength at 0° and 90° to warp.
F_{xy} = ultimate shear strength at 45° to warp.
$G_{\alpha\beta}$ = shear modulus at 0° and 90° to warp.
G_{xy} = shear modulus at 45° to warp.

In conclusion it appears that the picture frame method presented is satisfactory for obtaining shear stress design information for laminated glass reinforced plastics. Compared to the picture frame method, the Forest Products Laboratory method of calculating shear properties from tensile properties gives results which are conservative. This should be taken into consideration when reducing these values for minimum design allowables.

—■—

Errata

In the article "Polypropylene—Its Properties and Processing Characteristics" published in the September SPE Journal, page 1039, the cost of acrylic resin was shown to be $0.070¢ per pound, and for nylon $1.40-$1.50 per pound. Current prices for these materials are $0.50 for acrylics and $0.98-$1.26, per pound, for nylons.

•

On the Table of Contents page, September SPE Journal, under the listing of the article Porous Plastic Laminates, it was stated: "A method for preparing void free complex shaped resin-fabric laminates." It should have been stated that the method was for preparing laminates **with** voids in order to permit diffusion of sweat.

Quality Control Check-List and Procedures for Fluorocarbon Resins

P. E. Thomas

E. I. du Pont de Nemours & Co. Inc., Polychemicals Department

The terms TFE-fluorocarbon and FEP-fluorocarbon are used to further identify "Teflon" resins. TFE-fluorocarbon resins (TFE meaning tetrafluoroethylene) are homopolymers and are processed by cold forming and sintering methods. FEP-fluorocarbon resin (FEP meaning fluorinated ethylene-propylene) is a recently commercialized copolymer which can be injection molded or melt extruded (10). Most of the important properties of FEP and TFE-fluorocarbon resins are essentially equivalent; the principal difference being that FEP resins have a 100°F lower continuous service temperature.

Testing FEP Resin Parts

The mechanical strength of injection molded or melt extruded FEP-fluorocarbon resins is much less subject to fabrication variables than that of TFE-fluorocarbon resins. With FEP resin the major causes of variations in quality are surface roughness or delamination and thermal degradation.

In the case of injection molded parts, the following control tests are suggested:

1. **Oven aging at 480-520°F. for 1 hour.**
   This test will reveal whether a sample is internally delaminated. Delaminated samples will develop a severe fish-scale-like appearance after this heat cycle.
2. **Tensile tests.**
   Tensile strength and particularly ultimate elongation appear sensitive to both thermal degradation and delamination. In small parts that cannot be tested in tension, crush or flex tests should be applicable. In general both tensile strength and ultimate elongation decrease as the extent of delamination increases (1). Although severe thermal degradation lowers both tensile values, moderate thermal degradation may be masked by interactions between thermal degradation and delamination.

Work on tests that specifically measure the extent of thermal degradation is still in progress and will be reported on at a later date.

In testing extruded wire coatings of FEP resin, standard electrical test techniques that measure physical integrity of the insulation seem to be all that is needed.

From an overall point of view it appears that quality control tests on fabricated FEP resin should follow the paths that have been established for testing other non-plasticized, semi-crystalline thermoplastics such as polyethylene. With TFE-fluorocarbon resins a different approach is necessary, as the following sections will discuss.

Test methods and equipment for determining chemical composition and mechanical properties of fluorocarbon resins

Significance of Quality Control Tests For TFE Resins

The four tests that are commonly used for routine quality control purposes are dielectric strength, tensile strength, ultimate elongation, and measured specific gravity. These four have been selected because of their simplicity, applicability to a variety of shapes, good reproducibility, and sensitivity. The significance of these tests is explained in the following paragraphs and the relation between them and the basic quality factors is explained.

1. Dielectric Strength

The dielectric strength is controlled by the degree of microporosity. It is independent of the level of crystallinity and molecular weight. *Table 1* shows that dielectric strength correlates with the size and number of microvoids visible with the aid of a microscope.

As with other plastics the dielectric strength expressed as volts per mil increases as the thickness decreases. For example, 1/32 inch thick sheets of equivalent quality to

Table 1. Relation of Dielectric Strength of TFE-fluorocarbon Resin Sheets to Degree of Microporosity

Sample	Appearance of Cross Section in Microscope	Dielectric Strength Volts/Mil*
A	No visible voids at 100X magnification	760
B	Scattered .0001 in. diameter voids within particles	575
C	Scattered .0005 in. diameter voids between particles	445
D	Numerous .0005 in. diameter voids between particles	250

* 1/16" sheets—Immersed in A-80 Transformer oil per ASTM D149-55T.

Table 2. Effect of Microporosity on Tensile Strength and Elongation of TFE-Fluorocarbon Resin Sheets*

Sample	Extent of Microporosity	Tensile Strength lb./sq. in.	Ultimate Elongation percent
A	Negligible	3600	390
B	Slight	2520	350
C	Moderate	2020	300
D	Severe	1800	170

* Free-cooled 1/16" specimens with relative crystallinity of 65-68%. Tested by ASTM method D1457-56T. See **Table 2** for appearance of samples when viewed with microscope.

sample A in Table 2 have a dielectric strength of 1040 volts/mil and 1/8 inch thick sheets have a dielectric strength of 480 volts/mil. This thickness effect should be considered when setting individual specifications.

2. Tensile Strength and Ultimate Elongation

The tensile strength and ultimate elongation depend to some degree on all five basic quality factors. *Table 2* points out that the degree of microporosity (same samples as in *Table 1.*) has a significant effect. Limited data indicate that the amount by which tensile properties are reduced by microvoids depends on the percent crystallinity. Microvoids have their greatest effect in low crystallinity products.

There is definite evidence which indicates that tensile strength decreases as percent crystallinity increases. On the other hand, ultimate elongation has been shown to increase and then decrease as crystallinity increases (5, 9).

The degree of orientation also affects tensile properties. In general, in the direction of orientation, tensile strength is increased, but ultimate elongation is decreased.

While all flaws can lower the tensile strength to some degree, imperfect fusion between successive charges in extruded rod and heavy wall tubing are probably the defects of most common concern in ram extrusion. Usually, the tensile strength and ultimate elongation of these ram extruded products are controlled by the strength of the charge-to-charge bond.

3. Measured Specific Gravity

The measured specific gravity is obtained by water displacement and gradient tube techniques such as ASTM D792 or D1505. This is not necessarily the true specific gravity of the solid, however, since any microvoids present will affect the specific gravity. The true specific gravity is controlled by the percent crystallinity and is independent of microvoid content. In the range of 50 to 85 percent crystallinity, data now available does not agree with previously published data (2). Values for crystallinity are 3 percent units higher than the earlier values. The new values result from improved measuring techniques.

The measured specific gravity is related to the true specific gravity as follows:

$$\text{Measured Specific Gravity} = \text{True Specific Gravity} - \text{True Specific Gravity} \times \frac{\text{Volume Percent Voids}}{100\%}$$

The volume percent voids is called the void content. The true specific gravity is the specific gravity of the solid polymer in the specimen.

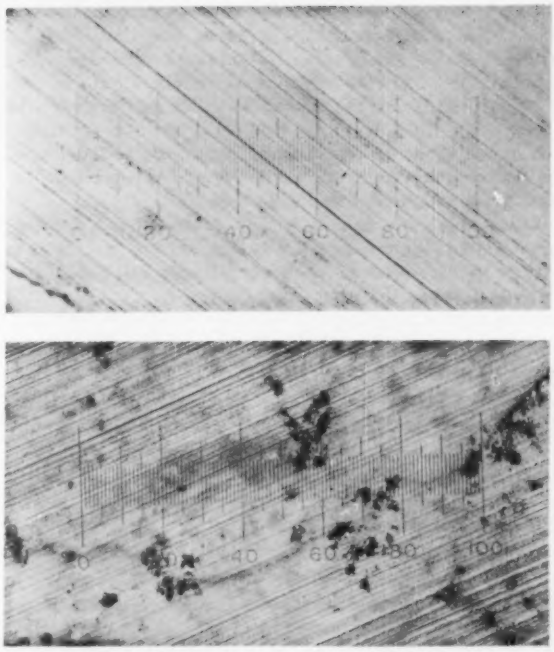


Figure 1. Photomicrographs of typical TFE-fluorocarbon resin sheet

Negligible Porosity (top) Moderate Porosity (bottom)

In the following sections the meanings of void content and crystallinity are further examined and newly developed methods of measurement are described.

Research Tools for Measuring Basic Characteristics

To supplement the indirect quality control methods, a number of laboratory techniques have been developed to check directly the presence of macroflaws, the extent of microporosity, the percent crystallinity, and the molecular weight. As yet, quantitative ways for determining the degree of orientation are not fully developed. Because of their complexity, these methods for checking basic characteristics are not ordinarily suited to routine product testing. These research tools do aid, however, in understanding and interpreting reasons for quality variations.

For detecting macroscopic flaws X-ray radiographic examinations may be employed. Sufficient views should be taken to give complete coverage of the piece. In parts more than two inches thick, at least two views taken 90° apart are needed. ASTM method E94-52T may be used as a guide in establishing testing procedures. While X-ray radiographic methods are satisfactory for detecting macroscopic flaws, they are not sensitive enough for detecting microscopic voids. A number of methods developed for this purpose are discussed in the following paragraph.

There are three methods in use for determining the degree of microporosity:

1. Microscopic inspection.
2. Visual examinations with and without the use of dye penetrants.
3. Comparison of measured and true specific gravity.

Microscopic techniques offer a valuable method of qualitatively checking the degree of microporosity and are primarily useful for "trouble-shooting".

To use this method, a sample 10 – 25 microns thick is microtomed and mounted on a slide. The slide may be viewed with the aid of either transmitted or reflected light. Usually a 5 – 250-fold magnification is employed.

Figure 1 illustrates the differences which can be seen with a microscope. It shows a 50X magnification of the cross section of two molded parts of varying porosity. In Sample A, the texture is uniform, whereas in Sample C, the numerous small black patches are indications of voids.

Visual inspection by a trained observer without a microscope can be of real value in detecting excessive microporosity and other gross quality defects. While it is difficult to convey in words the experience that enables one to judge varying degress of microporosity, some worthwhile hints are:

- It is easier to inspect for porosity by transmitted light than by reflected light.
- Use a powerful light source directly behind the sample. A large illuminated panel, with a ground glass surface is best for inspecting sheet stock.
- Small cracks are often more readily seen by viewing at an angle of 45° rather than looking directly through the sample.
- If permissible, cut off a thin section with a sharp knife and inspect it also.
- Prepare a series of standard comparison samples of varying degrees of microporosity. A simple method is to collect samples of varying measured specific gravity that have been processed by the same sintering and cooling conditions so as to have the same true specific gravity.

The value of vividly colored penetrants* as an aid in detecting microporosity or gross defects is subject to considerable differences of opinion among persons skilled in inspection techniques. Proponents of their use argue that penetrants intensify particle boundaries and make it easier for semi-skilled workers to grade the degree of porosity. Counter arguments are that sometimes relatively unimportant factors such as surface smoothness influence penetrant receptivity to such a degree that improper quality classifications can result. It is the author's opinion that penetrant methods are of some value when:

- The part to be tested is less than ¼ inch thick.
- Similar parts have previously been tested and comparison standards of both acceptable and non-acceptable quality are available.
- An agreement has been reached by the end user and fabricator as to the significance of occasional structural flaws. Such flaws as edge cracks and adhered flakes of resin in fabricated sheet, and saw marks or nicks in the surface of rod fall in this classification.

The volume percent voids or the void content is one measure of the degree of microporosity. The following equation defines the void content:

$$\text{Percent Void Content} = \frac{\text{True Specific Gravity-Measured Specific Gravity}}{\text{True Specific Gravity}} \times 100$$

Due to the combined errors of true specific gravity and measured specific gravity determinations, it is difficult to distinguish among samples having less than 0.5% voids. The precision of void content measurements is as good as ± 0.2% in homogeneous samples but may be no better than ± 0.5% in non-uniform samples.

* For example, Spot-check (R)—Magnaflux Corp., Chicago, Illinois.

Useful information about the quality of a fabricated part may be obtained if the crystallinity or true specific gravity is known.

A number of techniques have therefore been investigated for determining these data. These methods include: torsional damping (torsion pendulum—Reference 4), infrared spectroscopy (3), ultrasonic ("Reflectoscope"—Reference 8), rebound resiliency (Scleroscope**—Reference 8), and X-ray diffraction (7). The infrared and the torsional damping techniques appear to be the most sensitive methods and warrant further discussion.

In the infrared method a thin slice is cut from the specimen, mounted in a spectrometer and the absorption intensities of bands at two wavelengths are measured. The ratio of the intensity of the absorption band in the spectrum of the sample at 12.85 microns to that at 4.25 microns decreases linearly as the true specific gravity increases (3).

With the torsion pendulum* *Figure 2*, one end of a machined specimen is clamped to a top support. On the lower end of the sample a moment arm is clamped. The geometry of the clamps and the size of the moment arm are based on the sample geometry. By gently oscillating the moment arm the sample is subjected to small twisting or torsional forces, causing it to oscillate about the support axis. By measuring the period of oscillation the torsion modulus may be calculated. This value is directly proportional to the true specific gravity.

The true specific gravity based on an average of two infrared determinations on a given sample is precise within ± .003 specific gravity units (95% confidence limits). The true specific gravity for an average of two torsion pendulum

** Shore Instrument Company.

* Baldwin Lima Hamilton Co., Waltham 54, Massachusetts Oak Engineering Co., Gloucester City, New Jersey.

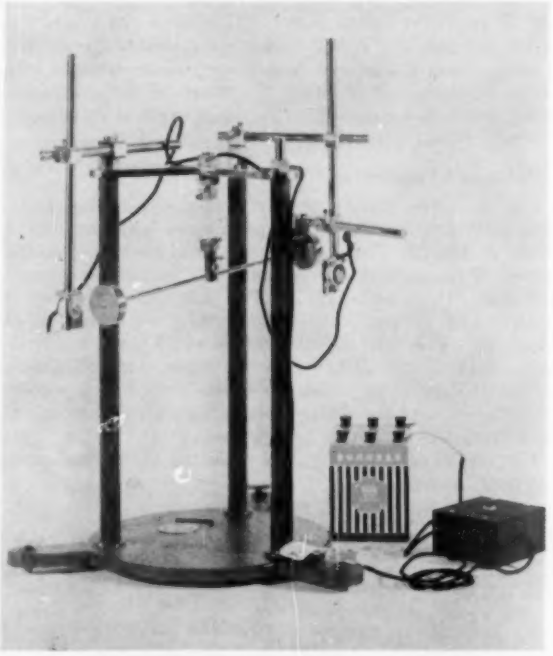


Figure 2. Torsion Pendulum. By measuring the period of oscillation, torsion modulus, which may be related to true specific gravity, may be calculated

determinations is precise to within ± .002 specific gravity units (95% confidence limits). It should be noted, however, that the above precision values are based on experience with a limited number of instruments and that inter-laboratory accuracy has not yet been adequately established.

While the torsion pendulum gives slightly better reproducibility than the infrared method, it is less versatile. The cost of the torsion pendulum is considerably less than the cost of a suitable infrared spectrometer.

Torsion pendulum specimens must be at least .010 inch thick and preferably .020 inches. With present instruments, flat specimens up to ⅛ inch thick and rod specimens up to ¼ inch in diameter can be tested. Thicker specimens must be machined. Surface roughness and excessive thickness variations interfere with accurate modulus determinations. Specimens should feel smooth and vary less than 5 percent in thickness along their length. Theoretically any length specimen can be used. Results to date indicate, however, that the specimens should be at least 2½ inches long.

With both methods, orientation within the specimens introduces errors. Because means of correcting for these errors are currently unknown, the true specific gravity of paste extruded wire coatings, tubing and film, and coined sheeting cannot yet be accurately measured. With the paste extruded products, however, apparent specific gravity measurements may be used to estimate the degree of crystallinity since the void contents are normally low.

The degree of crystallinity is controlled by the molecular weight and the length of time that a part is maintained within the temperature range for rapid crystallization (585°-620°F). By reheating fabricated parts according to a standard thermal cycle, relative molecular weights may be estimated through crystallinity or true specific gravity measurements. In low void content parts, relative molecular weights may be approximated from the apparent specific gravity measurements. Details on the standard thermal cycles may be found in ASTM method D1457-56T.

Practical Crystallinity Limits

Recent papers (5, 9) have discussed at length the influence of the degree of crystallinity and voids on properties of fabricated TFE-fluorocarbon resins. A number of questions have arisen, however, that point to the need for further clarification of normal limits for these basic variables. While theoretically the percent crystallinity or true specific gravity can be controlled over a wide range, there are certain practical limits. For instance, in parts thicker than about ¼ inch it is not possible to cool the interior fast enough to reduce the crystallinity below about 55%. Even in thin films rapidly cooled in water it has not been possible to reduce the crystallinity below about 47% (true specific gravity 2.135). An important point to keep in mind, therefore, is that measured specific gravities below 2.135 reflect some voids in any specimen.

At this early stage in the commercial utilization of methods for measuring crystallinity we feel that crystallinity values should not be directy specified. Where a particular crystallinity-dependent property is felt to be critical, we suggest that meaningful specifications be placed on the measured specific gravity.

How to Specify Typical Fabricated Parts

When setting property and tolerance specifications, the needs of the application must be balanced against the capabilities of both the resin and the method of making the part. All too often the needs are considered and designs are frozen before any suppliers of fabricated parts are consulted. This inevitably leads to confusion and inefficiency and often increases costs for the sake of expediency.

As an aid in tailoring specifications to wed design needs to the capabilities of fabricated fluorocarbon resins, the following suggestions are offered:

1. At the inception of a design idea, engineers should acquaint themselves with a broad picture of the properties of fluorocarbons as given in general texts.
2. As soon as the preliminary design is on paper, the mechanical properties and dimensions needed for the application should be reviewed. A number of articles on designing have appeared in the literature and may be consulted (9). Also at this point competent suppliers of fabricated parts should be consulted. Usually there are several quality grades of a given fabricated form. By having a supplier point out what is available at an early stage, it is often possible to adjust the design to accommodate the most economic usage of the material.
3. Once the design is frozen, there are several routes towards setting specifications. For stock shapes such as sheets, rods, and tubes a number of manufacturers' specifications have been prepared by fabricators of fluorocarbon resins under the auspices of the Society of Plastics Industry, Inc., 67 W. 44th St., New York 36, New York. In general, these specifications will cover more than one quality grade so that purchasers may select the type best suited for a given application. Other specifications are now being prepared by the American Society of Testing Materials, the Society of Automotive Engineers and various military agencies.

In special situations, such as the case where a company has a policy of writing their own specifications, the previously cited sources may not be satisfactory. In such instances the following guides on dimensional tolerances and test methods may be useful.

Factors to Consider When Specifying Dimensions

When setting dimensional tolerances there are two important factors that should be kept in mind. First, TFE-fluorocarbon resins have a high coefficient of thermal expansion, particularly over the range 66-70°F. Thus the ambient temperature for measuring dimensions should be specified. To illustrate the importance of this point, a part with a diameter of 1.000 inches at 73°F will contract about .003 inches when cooled to 66°F and expand nearly .001 inches when heated to 80°F. In cases where parts are being checked against tight tolerance specifications, measurements should normally be made at 73°F ± 2°F on parts previously held at this temperature for at least 16 hours. The second factor to remember is that "Teflon" can be deformed even by relatively low loads. Sometimes this is an advantage because slightly oversize or undersize parts can be deformed to fit. On the other hand, false tolerance readings can be obtained if micrometers are excessively tightened. Where applicable, an optical comparator is often the best way of checking dimensions.

The dimensional stability at elevated temperatures is controlled by the degree of orientation along with any frozen-in-stresses caused by uneven cooling after sintering. As a means of detecting differences in dimensional stability within a reasonably short period, parts are commonly heated to 550°F for 1 hour for each ¼ inch in the thickest section. In instances where dimensional stability at high temperatures is critical, this fact should be clearly noted since it can be controlled by proper choice of fabrication conditions.

Suggested Test Methods for Various Shapes

The box at right gives specific tests for checking the quality of extruded rod, molded sheet, molded parts, and tapes or films made from TFE-fluorocarbon resin.

Melting point measurements are suggested as an identification test to insure that a part is actually made from TFE-fluorocarbon resin. FEP-fluorocarbon resins may be distinguished from TFE-fluorocarbon resins by this test. "Teflon" 100, the presently available grade of FEP-fluorocarbon resin, melts at 545°-565°F as compared to 603°-639°F for all grades and granulations of TFE-fluorocarbon resins.

In the case of extruded rod, tensile strength and ultimate elongation are the standard methods used to measure quantitatively the strength of the charge-to-charge bond. There are three other qualitative methods sometimes used for the purpose. X-ray radiographic inspection has previously been discussed. Mandrel bend tests have been suggested for testing rods smaller than one inch in diameter (11). Still another method consists of resintering an unconfined section of a rod at 700°-720°F for a period of 1-4 hours depending on the rod diameter. Extruded rods with poor charge-to-charge bonds will develop distinctly visible cracks as a result of this heat aging cycle.

With extruded rods dielectric strength and measured specific gravity methods are suggested for checking for excessive microporosity.

For testing sheet, dielectric strength and dye penetrant methods are used to check for microporosity. Low measured specific gravities will also indicate this. The main purpose of measured specific gravity determinations, however, is to provide an approximate measure of the percent crystallinity. Tensile strength and elongation provide an all around indication of overall quality.

With molded parts, the X-ray and dye penetrant methods are suggested as means of detecting surface and internal flaws. Measured specific gravities are used to detect variations in the degree of microporosity and percent crystallinity, although these effects cannot be separated. The dimensional stability at elevated temperatures is usually determined by annealing a part at 550°F as discussed on p. 1251-2.

For tapes, pinhole counts and dielectric strength measure the degree of microporosity and the incidence of localized flaws. Measured specific gravity is primarily used as an index of the percent crystallinity as the void content is normally low. Tensile measurements, as in the case of sheeting, are used as an overall index of quality.

Here is a Convenient Check-List of ASTM Test Methods for you to Check Quality of TFE-Fluorocarbon Resin . . .

Extruded Rod

Test	ASTM Method
Tensile Strength	D-638, modified*
Ultimate Elongation	D-638, modified
Measured Specific Gravity	D-792-50, or D-1505-57T
Dielectric Strength	D-149-55T
X-Ray	E-94-52T
Melting Point	D1457-56T

Molded Sheet

Tensile Strength	D-1457-56T
Ultimate Elongation	D-1457-56T
Dielectric Strength	D-149-55T
Measured Specific Gravity	D-792-50 or D-1505-57T
Dye Penetrant	Non standard (Reference 11)
Melting Point	D-1457-56T

Molded Parts

Measured Specific Gravity	D-792-50T or Calculated from weight and dimensions
X-ray	E-94-52T
Dimensional Stability	Non-standard Heat to 550°F, cool slowly
Dye Penetrant	Non-standard
Melting Point	D-1457-56T

Films and Tapes

Tensile Strength	D-1457-56T or D-882-54T
Ultimate Elongation	D-1457-56T or D-882-54T
Pinhole Count	D-1389-56T
Dielectric Strength	D-149-55T
Measured Specific Gravity	D-792-50 or D-1505-57T
Melting Point	D-1457-56T

* Central section of test specimens machined to 60% of nominal diameter. Specimen length 5 inches. Tested at 2 inches/minute cross head speed.

Literature References

1. H. A. Larsen, G. R. de Hoff, N. W. Todd—*Modern Plastics*, August, 1959.
2. P. E. Thomas, J. F. Lontz, C. A. Sperati, and J. L. McPherson—*SPE Journal*, Vol. 12, Number 6, June, 1956.
3. R. E. Moynihan—*Journal American Chemical Society*, 81, 1045 (1959).
4. N. G. McGrum—*J. Pol. Science*, Vol. 34, p. 355-369 (1959)
5. C. A. Sperati, J. L. McPherson—"The Effect of Crystallinity and Molecular Weight on Physical Properties of Polytetrafluoroethylene", presented at 130th National Meeting of American Chemical Society at Atlantic City, September (1956).
6. R. C. Doban, C. A. Sperati, B. W. Sandt—*SPE Journal*, Vol. 11, No. 9, November (1955).
7. R. H. H. Pierce, W. N. D. Bryant, and J. F. Whitney, Chicago Meeting of American Chemical Society, September (1953).
8. W. G. Simeral, Du Pont, Polychemicals Department, Conference with members of Fluorocarbons Division of SPI, September (1957).
9. "Designing with 'Teflon'"—Article in *Machine Design*—September 5, 19, October 3, 17 (1958).
10. R. S. Mallouk, W. B. Thompson—*SPE Journal*, October (1958).
11. I. D. Press—*Materials and Methods*, 38 (1953) July.
12. F. C. McGrew, *Modern Plastics*, November, 1957, p. 162, 273, 275.

Adhesives for Poly(Vinyl Chloride) Shoes

R. J. Carey
Compo Shoe Machinery Corp.

One of the most critical factors in adhesive formulation is the proper choice and incorporation of plasticizer. Unfortunately, standard adhesives are limited in their capacity to absorb plasticizers. When that limit is exceeded the physical properties of the standard adhesive degrade appreciably. This is particularly apparent when such adhesives are used on premolded highly plasticized vinyl soles. Ordinary cements leach or extract so much monomeric plasticizers from the soling that the adhesive films are excessively degraded. Such adhesives exhibit very tacky surfaces or indeed appear not to dry at all. Plasticizers still are very much of a problem but their solubility in the cement solvents now becomes a major factor.

One suggested approach was the exploration of rapid dry solvent systems and forced drying systems for the adhesives to minimize the contact time of the adhesive solvent with the highly plasticized vinyl surfaces. The results to date of work on this method of approach have not been too encouraging. At best only limited success has been attained such that widespread use in shoe factories would be hampered by the equipment and space requirements.

The historical approach—that of using a cement as a plasticizer acceptor while building up resistance of the cement to degradation—was more successful. Sufficient different cement systems were successfully devised on this basis to demonstrate the feasibility of this approach. Each was formulated on the basis of cross-linking one or more of the ingredients in the adhesive film to withstand softening by plasticizers. At the same time, the adhesive film was not made so resistant to plasticizers that the adhesive would be pushed off the vinyl by continued migration of plasticizers.

Some of these adhesive systems will not be used commercially for various reasons. One adhesive has a toxic organic cross-linking agent; another uses an inorganic catalyst that has produced dermatitis. Fortunately, several adhesives are available that appear to be quite safe for general shoe factory use. These are cross-linking systems also, but toxicity and dermatitis are not factors. One type is a two-cement system rather than a two-part cement to avoid measuring and mixing of curing agents in the factory. The catalysts or crosslinking curing agents are divided between two cements which are quite stable in themselves. One cement is applied to vinyl soling and the other to the shoe upper material. When they coalesce and fuse together in the sole-attaching operation, cross-linking occurs over a period of twenty-four hours to several days depending upon the ambient temperatures. A second cement system is one part and exhibits good stability at room temperatures. Its cross-linking agents are triggered by a short exposure to elevated temperatures. This one-cement system is particularly suited for use on injection molded shoes wherein a two-cement system would present difficulties as objectionable, if not more so, than those encountered with a two part cement. The initial plasticizer resistance of these adhesives is quite good but this property improves as the curing and cross-linking of the adhesive films progress. The degree of bond strength varies with the vinyl formulation. In general, it approximates those obtained from high quality rubber soling materials.

These new vinyl cements on soft thermoplastic soling materials present a new problem. Since these adhesives are basically harder than any sole-attaching adhesives in common use with the exception of nitrocellulose cements, the problem of activation is quite serious. Activation is the process of rendering an adhesive film into such state or condition that it will readily weld, fuse or coalesce with another cement film while under pressure. Sole-attaching cements are commonly solvent-activated as is the case with pyroxylin or nitrocellulose adhesives or are heat activated in the case of vinyl adhesives, nitrile adhesives, and the harder neoprene adhesives. Some cements are used in a pressure sensitive state especially the softer neoprene and some nitrile adhesives. This latter process actually uses solvent retention as the activating medium.

While the new vinyls could be solvent activated, the poor "green" strength of vinyl materials would present a problem on some shoe constructions. There must also be considered the fact that the short time-dwell sole-attaching presses now in such wide-spread use in the industry might not be suitable. In the past, solvent activation of adhesives on non-process materials has always presented problems especially because of the influence of ambient atmospheric conditions on solvent release.

On the other hand, heat activation which is practically independent of weather conditions causes distortion of vinyl soles when conventional heat activators are used. The Compo Shoe Machinery Corporation has devised a new activator with controlled infra-red activation to melt these cement films without distorting the vinyl soles. With this activator it is necessary to heat the cement films on both the shoe and sole to insure sufficient softening of the cements. Because of the necessity to limit the quantity of heat absorbed by the sole while still softening the cement film, it is difficult to transfer a sufficient quantity of heat to the shoe to activate properly a cold cement film. Therefore, both shoe and sole must be heated. This entire cement process with the new activator is now undergoing field trials with very encouraging results to date. Standard shoe factory equipment with the exception of the activator is employed. This includes the use of standard sole-attaching presses, cementers, roughers and finishing machines.

The future for vinyl plastics in the shoe industry looks extremely bright particularly in expansion into the shoe soling field. With the work now going on to establish industry standards for testing vinyl materials and vinyl adhesion, and the cooperation of extensive testing and field trials by participating firms, there is every hope for success of this latest development of the plastics industry.

SOCIETY ACTION

Reynolds to Lead SPE in 1961

Lampman, Delmonte, Malone and Berutich elected to other major Society offices at October 18 Council meeting.

SPE's new officers for 1961. Seated, left, Frank Reynolds, and at right, John Berutich. Standing, left to right, Maurice Malone, James Lampman, and John Delmonte

FRANK W. REYNOLDS, *President*

On the staff of International Business Machines Corporation since 1928, Frank W. Reynolds has been involved in plastics for 20 years. In 1940 he was assigned to the newly organized Plastics Laboratory at Endicott, N. Y., and has served successively as mold designer, consultant and as Manager of the Laboratory since 1951.

Mr. Reynolds has been an SPE member since 1950. He is a charter member of the Binghamton Section and has served as its President and Councilman. In 1958 he was Society Membership Chairman, in 1959 Society Secretary and in 1960 First Vice-President. During these last two years he served also as Administrator of SPE Professional Activity Groups.

JAMES R. LAMPMAN, *1st Vice President**

James R. Lampman, a native of Lansing, Michigan, is Manager of the Organic Chemical Engineering Materials and Process Laboratory of General Electric Company at Syracuse, N. Y. He was graduated from Michigan State University with a B.S. in Chemical Engineering in 1948 and joined G. E. immediately.

An SPE member since 1955, he was instrumental in organizing the Central New York Section. He has served as that group's Councilman since 1958. In 1959 he was Society Membership Chairman and in 1960 was SPE Secretary.

JOHN DELMONTE, *2nd Vice President**

John Delmonte was graduated with a B.S. in Electrical Engineering from New York University in 1933 and received his M.S. in the same subject the following year from Massachusetts Institute of Technology. He has represented the Southern California Section as Councilman the last three years and is currently Chairman of the Western Section of SPI. He was a member of the Executive Committee of SPE and Administrator of Meetings during 1959. He is President and General Manager of Furane Plastics, Inc., having founded that company in 1945. He is the author of three books and numerous technical articles in trade and professional journals.

JOHN M. BERUTICH, *Treasurer*

John M. Berutich has worked in the plastics industry since graduation from Lehigh in 1937. He served in various engineering and supervisory capacities for General Electric Company prior to joining the sales staff of Haveg Industries in 1959 when that company purchased the GE molding operations in Louisville, Kentucky.

An SPE member since 1956, he is a past President of the Kentuckiana Section and has been that group's Councilman since 1959. He was Chairman of the Society's Student Membership Committee in 1959 and Constitution and By-Laws Committee in 1960.

MAURICE F. MALONE, *Secretary*

Maurice F. Malone was awarded both a B.S. in Chemistry from Loyola College and a Bachelor of Commerce degree from McGill University. In 1952 joined the laboratory staff of Canadian Resins and Chemicals. Following three years as a sales representative, he was promoted in 1956 to his present post of Sales Development Supervisor in Montreal.

An SPE member since 1953, Mr. Malone was elected Councilman representing the Quebec Section in 1958 and in 1960 was appointed to the Society Executive Committee and Administrator of Publications.

** The titles of First Vice-President and Second Vice-President will become Vice-President, Engineering and Vice-President, Administration, respectively, should a new organization plan for the Society receive final Council approval on January 23, 1961.*

Edited by
Thomas A. Bissell, *Executive Secretary*

the few extra pennies that buy next year's vinyl business

We believe that these few pennies, invested in the right plasticizer, buy next year's vinyl business . . . the repeat business that stems from confidence in the consistent quality and performance of your product.

Why? Because these few additional pennies buy a proven low-temperature winner . . . Plastolein 9058 DOZ. We'll admit that cheaper low-temperature plasticizers appear tempting. But do they warrant putting the future of your business in jeopardy?

With time-tested Plastolein DOZ you are sure of lasting low-temperature flexibility . . . excellent heat and light stability . . . low volatility . . . unusually good "hand" . . . all the qualities that lead customers to buy (and buy again) with confidence. Isn't this your strongest appeal for next year's vinyl business . . . your best assurance of continued profit?

If you are not familiar with Plastolein 9058 DOZ, send for evaluation samples or full information today. Write Dept. J-11.

PLASTOLEIN® PLASTICIZERS

Emery

ORGANIC CHEMICAL SALES DEPT., EMERY INDUSTRIES, INC., CAREW TOWER, CINCINNATI 2, OHIO

VOPCOLENE DIVISION, LOS ANGELES — EMERY INDUSTRIES (CANADA) LTD., LONDON, ONTARIO — EXPORT DEPARTMENT, CINCINNATI

FERRO UNIFORMAT

Uniform in weight, coverage, strength

Reinforce with a *fiber glass mat* completely free of weak areas caused by variations in mat weight or pattern. With UNIFORMAT's even texture, you're sure of strength uniformity in every direction. Every roll is alike. We check each carefully against Ferro's high-quality standards at every stage of production.

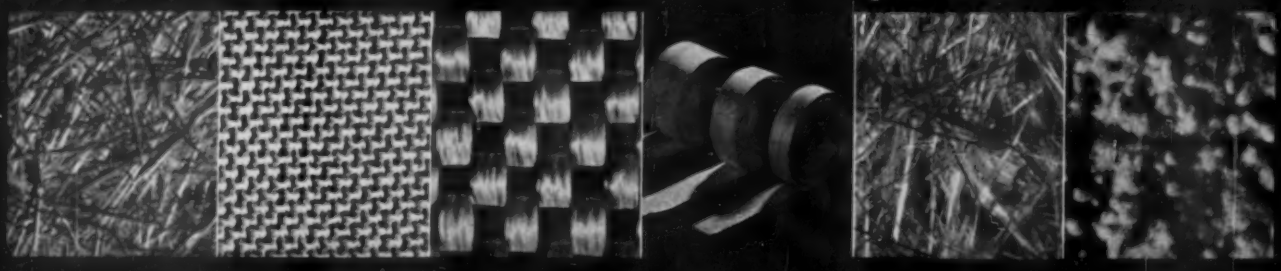
UNIFORMAT handles, tailors, laminates easily without tearing. Every roll must conform to close "specs." Write for samples, prices.

FERRO

FERRO CORPORATION
FIBER GLASS DIVISION
Nashville 11, Tenn. . . . Huntington Beach, California

Other Ferro plants in Argentina, Australia, Brazil, Chile, England, France, Holland, Hong Kong, Japan, Mexico and South Africa. Write for full addresses.

CHECK FERRO FIRST . . . for your complete fiber glass needs!



Mat | *Fabric* | *Woven Roving* | *Tape* | *Chopped Strand* | *Milled Fiber*

DOW | RESINS

BRINE LOSES ITS BITE

When "reefer" hatch covers are preform moldings

Refrigerator car hatch covers take a beating from weather, hard use, and corrosive brine. Preform molded polyester hatch covers prove they can take it, and save money for the user, as well!

The Plastics Division of General American Transportation Corporation preform molds the durable hatch covers shown above for Standard Railway Equipment Manufacturing Company. The results are economical covers with excellent resistance to weathering and to the attack of salt; they won't warp or lose their strength and they last the life of the car with little or no maintenance.

Reinforced polyester moldings are low in cost, too. Nearly any configuration can be molded, greatly reducing the number of costly production operations normally required by other materials.

Preform moldings offer advantages in cost, in production ease, in long life under difficult service conditions; and the types of products for which they can be used are virtually unlimited. The Dow Chemical Company supplies the basic monomers for polyester resins for premix, preform and mat moldings—Dow styrene and Dow vinyltoluene.

For information on these Dow monomers, write THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Sales Department 1967EX11.

See "The Dow Hour of Great Mysteries" on NBC-TV

THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN

NOW AVAILABLE FROM NEW PLANT...

SANTICIZER® 409

ASSURED SUPPLY

Monsanto's new multimillion-lb./year plant producing SANTICIZER 409 is now onstream at Everett, Mass. Production was multiplied greatly in response to rapid acceptance of this versatile plasticizer by the plastics industry.

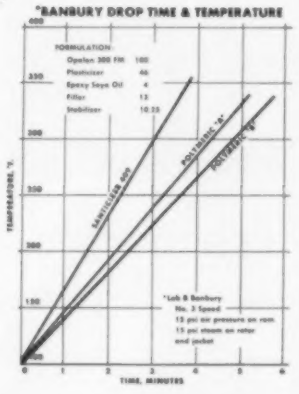
IMPROVED PERMANENCE

SANTICIZER 409 is highly compatible and imparts good performance properties to vinyls. Volatility is low. Heat stability and light stability are excellent. Comparative tests show that SANTICIZER 409 resists solvent extraction best of all lower-cost polymeric plasticizers. SANTICIZER 409 *stays put*, won't exude even in high humidity.

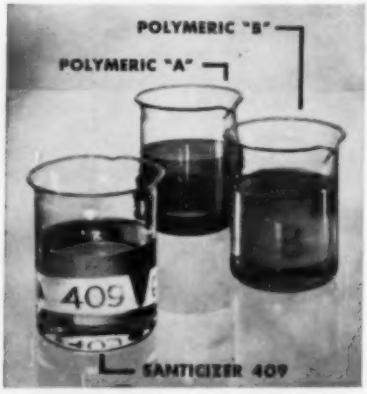
FASTER PROCESSING

SANTICIZER 409 has low viscosity, high solvency . . . for much faster fusion and extrusion. Helps prevent pinholes, "fisheyes," and roughness. You can count on SANTICIZER 409 to boost output, reduce processing problems, and assure optimum physical properties *within your processing-temperature range.*

FAST FUSION



OPTIMUM CLARITY



HIGH PURITY

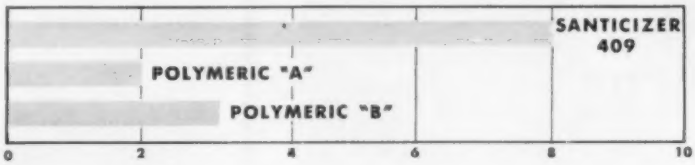
SANTICIZER 409 is clear, non-hazy, light-colored. Contains no flocculent matter that might weaken electrical properties or cause spotting in thin films and transparent sheeting. SANTICIZER 409 adds no odor to gaskets or wire insulation for refrigerators or other low-odor applications.

SUBSTANTIAL SAVINGS

Compare prices and specific gravities. SANTICIZER 409 gives compounders more plasticizer per dollar . . . *more profit per unit volume of compound.* And easier, quicker processing provides added savings.

WEEKS TO EXUDE AT 100% HUMIDITY, 60°C

HIGHER COMPATIBILITY



FOR BETTER INSULATION

Specify SANTICIZER 409 to simplify processing and assure superior electrical properties . . . especially for 105° C. appliance wiring, plastisols, and adhesive-backed insulating tapes. Vinyls compounded with SANTICIZER 409 show consistently high resistivity . . . *plus* excellent compatibility even in high humidity, superior retention of properties after heat aging, and no corrosion of copper.

FOR BETTER SHEETING, FILM, AND COATINGS

You can easily meet tough specifications with SANTICIZER 409 . . . for such products as automobile upholstery, adhesive-backed decorative film, unsupported sheeting, scuff- and extraction-resistant film, and corrosive-resistant protective coatings. SANTICIZER 409 improves processing properties. It's practically odorless. It doesn't migrate, imparts better low-temperature flexibility than many other polymeric plasticizers, and offers superior resistance to extraction.

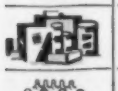
compare benefits with any other polymeric plasticizer

SANTICIZER 409 GIVES BETTER VINYL COMPOUNDS AT LOWEST COST

Monsanto

Monsanto, maker of more plasticizers than any other company, provides these benefits to customers:

precisely right plasticizer systems



mixed-shipment savings

able technical help in depth

IF YOU WANT better, lower-cost vinyl compounds . . . can you *afford* to ignore SANTICIZER 409? *Send today for illustrated Technical Bulletin PL-409* . . . and get samples and compounding help from Monsanto's Plasticizer Council.

MONSANTO CHEMICAL COMPANY
Organic Chemicals Division
St. Louis 66, Missouri

Please send me: ☐ Technical Bulletin PL-409 ☐ Test sample of Santicizer 409

NAME ..... TITLE .....

COMPANY .....

STREET .....

CITY ..... ZONE ..... STATE .....

ABOUT MEMBERS

Mr. Murphy

The formation of a new corporation Woodbridge Plastics Inc., to provide custom compounding of vinyl and polyethylene for the wire and cable, vinyl shoe, profile extrusion, and injection molding industries, was recently announced by **Kenneth B. Cary,** President and **Richard A. Murphy,** Vice President, Sales.

Daniel E. Strain has been appointed associate research manager of Du Pont's newly formed Polyolefin Division. Dr. Strain has been with the company since 1929 and is a recognized authority on hydrocarbon research.

Frederick W. Schneider has recently joined Marbon Chemical Div., Borg-Warner Corp. as group leader in charge of plastics applications and evaluations. He was formerly with Firestone Plastics.

Alan Corry has joined Chamberlain Laboratories' staff as research engineer. Formerly a research and development project engineer with the Electric Boat Division of General Dynamics Corp., Corry holds an M.S. degree in chemical engineering from the University of Rhode Island.

John W. Hinton recently joined Godfrey L. Cabot, Inc. as a sales development engineer. Hinton graduated from Yale with a B.S. degree in industrial administration. He comes to Cabot from Union Carbide Plastics Co.

H. D. Howard has been appointed vice president of Ray Products, Inc., Alhambra, Calif. Howard has been with Ray Products for 6 years, most recently serving as plant superintendent.

Modern Plastics Machinery Corp. has announced the appointment of **Bruno V. Menegus** as Chief Engineer. He is a graduate of Fairleigh Dickinson University and is a member of the Newark Section.

Gordon B. Thayer, staff specialist in technical service for Dow Chemical, has been named project manager to plan and set up new service operations for Dow's European customers. Thayer is an authority on injection molding and is a member of the Detroit Section of SPE.

Mr. Wheeler

Norton C. Wheeler, Jr. has been appointed research and development Manager of Davis-Standard, Div. of Franklin Research and Development Corp. His work will be directed primarily toward the development of high-production systems for all types of plastics extrusion.

Mario Petretti Dead

Southeastern Ohio Section Councilman, and 1949 President of SPE, dies suddenly on October 7

Mario Petretti as SPE President in 1949

The Society of Plastics Engineers lost a most dedicated and loyal member with the death of Mario J. Petretti. One of the pioneers of the plastics industry, he started his career with the Levittown Manufacturing Co. Brooklyn, N.Y., in charge of the Plastics Department, in 1931. In 1945, he set up the Plastics Division of the Noma Electric Corp., becoming General Manager. Subsequent positions held were, Chief Engineer with Continental Can Co. (1950), Chief Engineer and Vice President, Camfield Fiberglass Plastics, Inc., (1952), and Vice President, Product Techniques Inc., which position he held at the time of his death.

Never content to bask in the reflected glory of past achievements, Mario was a tireless worker who had an intense pride in his profession and his Society. This was exemplified in his letter reply upon being notified of his appointment as a Distinguished Member of the Society: "Needless to say, I am absolutely thrilled in receiving the notification . . . . ." In Council, where he served for many years, he was quick and eloquent in expressing his convictions, which sometimes were unpopular, if he believed them to be for the good of the Society. He was one who respected the judgment of his colleagues, although he did not always agree with them. Past President Peter W. Simmons (1957) represented the Society and the Past Presidents at the funeral held on Monday, October 9, at St. Patrick's Cathedral, Grand Haven, Mich.

Mr. Petretti is survived by his wife and three children.

The Society of Plastics Engineers laments his passing.

Mr. Maywald

Frederick J. Maywald has been appointed Vice President and General Manager of Modern Plastic Machinery Corp., extruding and blow molding equipment manufacturer, Clifton, N. J. A veteran of more than 20 years in the chemicals and plastics industries, his background includes associations with National Rubber Machinery Corp., Allied Latex Corp., Tecla Chemical Co., and Standard Latex Co. Other appointments for Modern Plastics Machinery Co. include: **Leslie J. Kovach** as Vice President in charge of blow molding, and **Casper S. Gilbert,** Sales Manager.

Durbin "Doc" Hunter has been elected Vice President and General Manager and a Director of Plastics Corporation of America, Stamford, Conn. The company manufactures polystyrene molding and extrusion resins.

C. Howard Adams, has been appointed manager of product engineering for Monsanto Chemical Company's Plastics Div. at Springfield, Mass. Also for Monsanto at Springfield: **Michael F. X. Gigliotte** appointed assistant director of engineering, and **Sidney Rankin** joins the research department, coming from Kordite.

Edward W. Bastian, vice president of Catalin Corp. of America, has been appointed general sales manager of the company. He will be responsible for the sales in all product lines and will make his headquarters in New York City.

Thomas M. Hamilton, field representative for Rohm & Haas in the upper New York State area, is now in charge of the Southeastern territory, with headquarters in Atlanta.

Carl A. Setterstrom, formerly general manager of marketing of AviSun Corp., has been named vice president of marketing for the Rexall Chemical Co.

A 12-man U.S. team of plastics experts will join with delegations of 20 other nations in Prague on October 17 for a six-day meeting aimed at establishing new international specifications and tests for plastics. Following SPE members are among the delegates: **Dr. Gordon Kline,** National Bureau of Standards, **Dr. Norman Skow,** Synthane Corp., **G. H. Williams,** Bell Telephone Labs, **E. Y. Wolford,** Koppers Co.

Ralph M. Winters has been promoted to Technical Service Manager—Film for AviSun Corp. Winters formerly worked for American Viscose and is a Duke University graduate.

Frederick T. Tulley has been promoted to the position of Manager, Sintrex Div., Amos-Thompson Corp., Edinburg, Ind. He will manage the new Amos Div. which will mold plastics by a new sintering process patented in Germany.

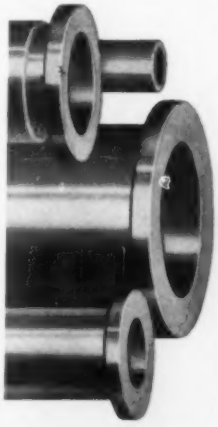
Rober Fehr joins F. J. Stokes Corp. as a sales engineer in the Rochester, N. Y. office.

Mr. Miksch

The Newark Die Company has elected **Nathan Miksch** President. He has been associated with the company since 1945.

only Xaloy

meets every requirement in extruder cylinders



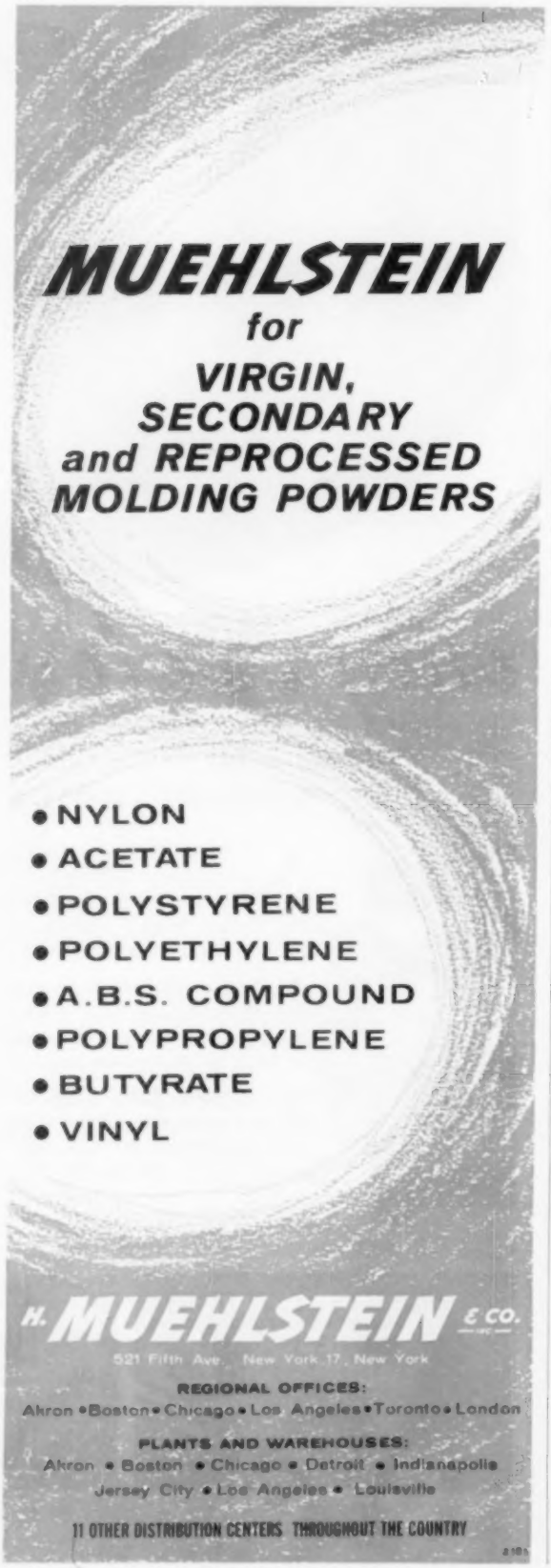
1 . . . **because** Xaloy *bimetallic cylinders* are available in *all* sizes, engineered to meet the individual requirements of plastics and rubber processors.

2 . . . **because** the mirror-smooth surface of Xaloy liners allows maximum production, hour after hour, in continuous service.

3 . . . **because** Xaloy cylinders have proven to be the most advanced liners for extrusion machines over the past 25 years.

WRITE FOR NEW XALOY DATA GUIDE

INDUSTRIAL RESEARCH LABORATORIES
Division of Honolulu Oil Corp.
961 East Slauson Ave.
Los Angeles 11, Calif.



SPE Publications For Sale

1960 Regional Technical Conference Preprint Books

1. **Plastics in Business Machines**—Binghamton Section, 8 papers, $2.50 members, $3.75 non-members.
2. **Plastics vs. Corrosion**—Golden Gate Section, 10 papers, $3.00 members, $4.50 non-members.
3. **Blow Molding**—Newark Section, 8 papers, $3.00 members, $4.50 non-members.
4. **Automation in Injection and Compression Molding**—Ontario Section, 9 papers, $3.00 members, $4.50 non-members.
5. **Plastics in the Petroleum and Chemical Industries**—North Texas Section, 8 papers, 63 pages, $2.50 members, $3.75 non-members
6. **New Horizons in Vinyls, and Plastics in the Shoe Industry**—Eastern New England Section, 13 papers, $3.00 members, $4.50 non-members.

Other Technical Conference Books Available

7. **16th ANTEC Preprint Book**—Volume VI, 1960, Chicago, 83 papers. $7.50 members; $12.50 Non-members. Single preprints of individual papers, Vol. VI, while they last, $0.25 each, members; $0.40 each, non-members.
8. **Stability of Plastics**—Baltimore-Washington Section; Nine 1000-word abstracts. $1.00 members; $1.50 non-members (See program page 897, Oct. SPE Journal).
9. **Plastics in the Shoe Industry**—St. Louis Section, 11 papers, $3.00 members, $4.50 non-members. (See program, September SPE Journal, page 820).
10. **Plastics in Packaging**—Golden Gate Section, 12 papers, $3.00 members; $4.50 non-members. (See program, October SPE Journal, page 899).
11. **Vinyl Plastics**—Cleveland Section, 8 papers, $2.50 members; $3.75, non-members. (See program, SPE Journal, August, 1959 issue, p. 745).
12. **Plastics Finishing**—Buffalo Section, 4 papers, $2.00, members; $3.00 non-members. (See program, SPE Journal, September, 1959 issue, page 823).
13. **Encapsulation, Printed Circuits, and Fluidized Bed Processes**—Northern Indiana Section, 15 of 23 papers presented. $3.00, members; $4.50, non-members. (See program SPE Journal, April, 1959, p. 319).
14. **Plastics in the Automotive Industry**—Detroit Section, 4 papers, $2.00, members; $3.50 non-members. (See program SPE Journal, May, 1959, p. 443).
15. **NATEC Preprint Book**—Volume I, 1959, Los Angeles, 20 papers. $5.00 members; $7.50 non-members (See program, September SPE Journal, page 788, and Abstracts on pages 815-817).

SPE Plastics Engineering Series

16. **Vol. II—"Processing of Thermoplastic Materials"**—E. C. Bernhardt, Ed., Reinhold Publishing Company 1959, 705 pages, $14.40, members; $18.00, non-members.

Special Publication

17. **Plastics for Architects, Artists and Interior Designers**—by Armand G. Winfield. An illustrated survey of some of the best uses of plastics in the building and decorative fields. $2.25

SPI individual members are entitled to SPE members' prices under a reciprocal agreement. Books will be mailed postpaid if money is enclosed.

Please send me the Following SPE Publications:

(The numbers of the books I wish are encircled below)

1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17

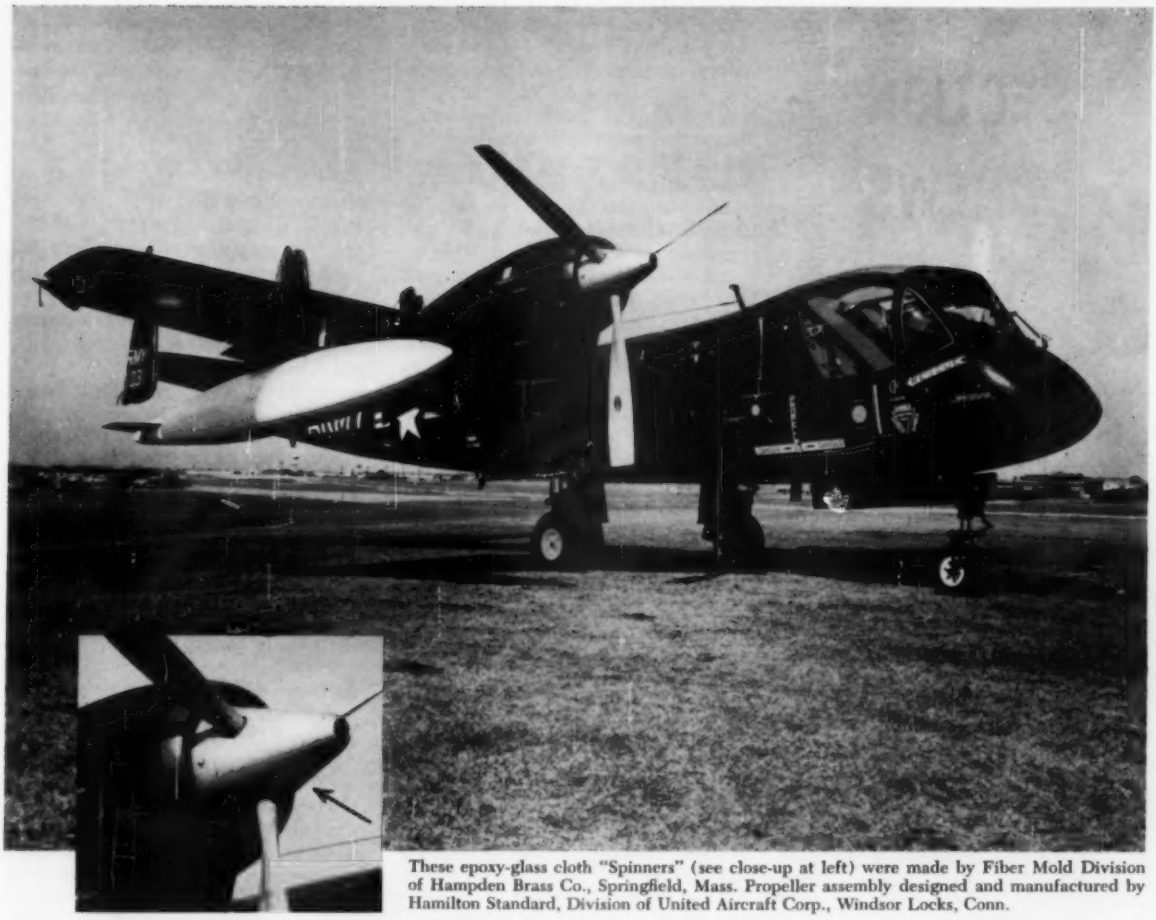
Name _____

Address _____

City _____ State _____

☐ SPE Member ☐ SPI Member
☐ NOT a member of either SPE or SPI

Mail coupon to the Society of Plastics Engineers, Inc.
65 Prospect Street, Stamford, Connecticut



These epoxy-glass cloth "Spinners" (see close-up at left) were made by Fiber Mold Division of Hampden Brass Co., Springfield, Mass. Propeller assembly designed and manufactured by Hamilton Standard, Division of United Aircraft Corp., Windsor Locks, Conn.

"SPINNERS" OF EPOXY-GLASS CLOTH

dampen vibration, maintain strength despite alternate icing and heating

One of the outstanding features of epoxy resin glass-cloth propeller "spinners" now being used on Grumman "Mohawk" airplanes is their predicted long, reliable service life. The epoxy-glass cloth "spinners," which incorporate molded-in wire element de-icers for the aircraft's propellers, possess excellent tensile strength and fatigue resistance—very important properties for a part that is subjected to severe vibration.

In addition, the wire heating elements, that are laminated right in with the glass cloth and impregnated with BAKELITE Brand epoxy resin-based compound, have excellent electrical insulation. The strength-to-weight ratio of the "spinner" is high and production costs are substantially reduced.

Here is another example that shows how BAKELITE epoxy resins possess the versatility, and physical and electrical properties necessary to meet exacting product requirements. For further information on BAKELITE Brand epoxies write to Dept. FF-132, Union Carbide Plastics Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y.

"BAKELITE" and "UNION CARBIDE" are registered trademarks of Union Carbide Corporation.

UNION CARBIDE

SECTION NEWS

New York

Filament Winding Session In New York Reinforced Plastics PAC

GEORGE LUBIN (Grumman Aircraft)

The New York RPPAC met at the Candlelight Restaurant in Manhasset on September 28, 1960. It was attended by approximately 90 members and guests.

The first speaker, James E. Fitzgerald of Brunswick Corporation, Marion, Va., discussed the techniques in filament winding used by Brunswick, particularly the Strickland "B" Process. This process has been used in manufacturing several missile nose radomes including the Bomarc, the Kingfisher and the Tartar, as well as aircraft radomes for Convair 106 Interceptor, Republic Advance 105, Chance Vought F8U and Grumman Intruder A2F.

Mr. Fitzgerald showed numerous slides illustrating the complex equipment required for this process and the many steps used during the winding operation. The largest part that can be made at present is up to 8 feet in diameter and 12 feet in length. The grinders used to finish the surface are capable of accuracies within .001", and by using an interferometer the radomes can also be ground to a dielectric thickness. Slides were also shown listing electrical, thermal, and mechanical properties of filament wound radomes. Mr. Fitzgerald then discussed advantages and disadvantages of this process.

The second speaker, one of the pioneers in filament winding, Mr. Richard E. Young of Hercules Powder Company, described the Young process for filament winding. An outline of his ideas is presented below.

The fundamentals of the filament-wound pressure cylinder were reviewed. The original balanced netting structure was developed in 1947-1948 utilizing a single helical winding system, which simultaneously formed the cylindrical vessel and retained appropriate end closures.

In 1954-1955 the ovaloid end concept was developed. This is a winding system comprising two components. One is of a low helix angle carrying the longitudinal loads and forming the integral end closures of the cylinder as well as carrying a small component of the girth load. The second member of this system consists of circular windings which carry the remainder of the girth load. The integral ovaloid end closure is so termed because its profile is not a common geometric shape and is the profile specifically required by a given netting pattern in the end windings so that the entire internal pressure is resisted by pure tension in the filament system. In considering this structure as a true netting structure, no structural dependence is placed on the resin neither is there any secondary bending or shear loading in the system.

The geometry of the above described system was illustrated by a slide and reference was made to more detailed development of the netting system in:

(1) HISTORY AND POTENTIAL OF FILAMENT WINDING
(2) THE ENVELOPE EFFICIENCY OF COMMON FILAMENT-WOUND SHAPES

Specific performance figures were discussed as were component materials and general details of the process.

Among those present were many well known figures in the plastics field including Hi Nathan, National Vice President; Bob Brinkema, the organizer and first president of the N. Y. Chapter; and Doctor Modigliani, a pioneer in the glass filaments. Also, there was Larry Wittman, Frank Nussbaum, Carl Lemonier, and Mal Riley.

Connecticut

New Applications for Polycarbonate Resins

K. G. Clarke (Du Pont)

The Connecticut Section held its first meeting of the year on September 9 at the American Brass Country Club in Naugatuck.

The guest speaker of the evening was Mr. R. J. Thompson, Manager of Polycarbonate Market Development, General Electric Company, Pittsfield, Massachusetts. Mr. Thompson's discussion concentrated on commercial applications of "Lexan", General Electric's new polycarbonate resin. The excellent combination of mechanical and electrical properties and good temperature resistance of "Lexan" make it a good candidate for many industrial applications: business machine components, pump impellers, telephone transfer clips, appliance sight glasses. Mr. Thompson also pointed out that polycarbonate makes an excellent photographic film base, and that a major producer of photographic equipment will introduce this product very shortly.

The very active question and answer period which followed hit primarily on price and processing techniques. Mr. Thompson indicated that a price below $1.00/pound was likely in the forseeable future.

Mr. Harlan Fisher, Watertown Manufacturing Company, Watertown, Connecticut, announced that the Club will hold a Ladies' Night this year, probably in December.

Mr. Ralph Esposito, Rockwell Manufacturing Company, Bridgeport, who is Program Chairman announced the program and speakers for the entire coming year.

Bartlesville-Tulsa

Plastics in India

A. L. Robbins (Phillips Petroleum Co.)

The first meeting of the year, which was held on September 13, featured an outstanding program. The after-dinner speaker, Mr. C. B. Garware, in a talk entitled "The Plastics Industry in India" stimulated a great deal of interest in India's latest efforts in the field. He discussed in detail the special problems encountered in India as well as the potential for future growth of plastics in India. He pointed out that very high quality molded and extruded parts are being made in India today. Also, a few resins are manufactured in India now and they hope to begin manufacturing their own processing equipment in the near future.

A long question and answer period following Mr. Garware's formal presentation gave evidence of the interest he generated in his country's industrial development.

Mr. Garware is a Director and Technical Coordinator of the Garware Plastics Company in Bombay, India. He is in the United States to learn more of our plastics and equipment.

Newark

Injection Molding

R. E. Christensen (Union Carbide Plastics Co.)

A symposium on injection molding was presented at the September 14th meeting of the Newark section. Improved mold filling techniques which

have received wide interest in the industry were outlined in three excellent, informative talks.

Mr. Lloyd Alexander of the Phillips Chemical Co. Plastics Division discussed multigating and its advantages. A number of pieces with recommended gating arrangements were shown by means of colored slides.

Mr. Cliff Weir of the W. R. Grace and Co. Polymer Chemical Division discussed valve gating with high density polyethylenes to obtain fast mold filling.

Mr. Judd Decker, Vice-President of Bopp-Decker Plastics Inc., described sequential impact molding, which was developed to permit the molding of thin-walled pieces. Mr. Decker also showed a specially designed internal nozzle heater used to accurately control heat to the material and prevent "freezing off" in hot runner molds.

Blow Molding RETEC

"Blow Molding Comes of Age" is the title of the RETEC which the Newark Section is presenting on November 18, 1960 at the Essex House in Newark, N. J. Bob Hoehn, Chairman of the RETEC Committee, reports that an outstanding group of blow molding experts have submitted papers.

North West Pennsylvania

Modernization of Equipment

Lloyd English (Louis Marx & Co., Inc.)

A dinner meeting was held on September 22. The meeting was called to order by George Schau, Vice President, and was attended by 33 members and 5 guests.

The speakers of the evening, introduced by Clifford Scantlebury, were Mr. Robert Watkins, District Engineering Manager, and Mr. Frank Moore, District Representative of the Bellows Air Valve Company.

Mr. Watkins gave an interesting background review of economic factors affecting our foreign competition, pointing out the urgent need for greater depth of modernization and automation of our industry, particularly on the manufacturing or fabrication level, as one important means of meeting this competition.

Mr. Moore followed up with an informative discussion supplemented by color slides of specific practical applications of air hydraulic systems used to automate manufacturing operations and increase productivity of older slower machines.

(*Continued on page 1267*)

for PLASTICS . . . specify the PROVEN temperature instrumentation–by WEST

- Complete selection of Controllers to suit Individual Requirements in Extrusion, Injection Molding, Blow Molding, Vacuum Forming and Heat Sealing.
- Compact, solid state, free from *vacuum* tube-problems, minimum supervision or maintenance. Specify on Original Equipment or purchase directly.

Gardsman by WEST

MODEL JP series provides *proportioning* heater control.

MODEL JPT-2 integrates control of *both* heating *and* cooling for frictional heat in extrusion.

MODEL JSB series provides *stepless* heater control within *extremely close* tolerance; especially appropriate for extrusion die or injection nozzle control.

THERMOCOUPLES—complete selection of standard Thermocouples—including melt, bayonet, compression types preferred in working plastics—or send us your specifications on specials.

Ask your West representative (see Yellow Pages) or write direct for Bulletins JP, JT, JSB and Thermocouple Data Book.

WEST Instrument CORPORATION
SALES OFFICES IN PRINCIPAL CITIES
4359B W. MONTROSE, CHICAGO 41, ILL.
British Subsidiary:
WEST INSTRUMENT LTD.,
52 Regent St., Brighton 1, Sussex
Represented in Canada by Davis Automatic Controls, Ltd

the trend is to WEST

Keep your
PRODUCTS
younger
longer

HARCHEM SEBACATE PLASTICIZERS

Keep your vinyl products from showing their age in use and they'll keep building good will and good volume for you.
Harchem Sebacate Plasticizers give vinyls built-in resistance to heat, cold, water or physical abuse.
Harchem offers four Harflex Sebacic Acid Esters. Check the list below for the one best suited to fight aging, weathering and wear for you.

will do it!

Plasticizer	Specific Gravity 25°/25°C ± .003	Viscosity 25°C, cps	Compatible With	Outstanding Characteristics
Dibenzyl Sebacate	1.035	21-22	Polyvinyl Chloride and Copolymers, Polyvinyl Butyral, Synthetic Rubbers	Excellent Solvation, Very Low Volatility, Permanence, Good Electricals, Low Temp. Flexibility
Dibutyl Sebacate	0.935	7.9	Vinyl Resins, Cellulose Acetobutyrate, Synthetic Rubbers, Rubber Hydrochloride, Polymethyl Methacrylate	Low Temp. Flexibility, Excellent Aging Qualities, Non-Toxic
Dimethyl Sebacate	0.986*	3.54 @30°C	Vinyl Resins, Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate, Acrylic Resins	High Solvency and Efficiency, Wide Compatibility, Concentrated Source of Sebacyl Radical
Dioctyl Sebacate	0.913	17.4	Polyvinyl Chloride and Copolymers, Polyvinyl Butyral, Synthetic Rubbers, Cellulose Nitrate, Cellulose Acetobutyrate	Excellent Low Temp. Flexibility, Low Volatility, Excellent Soapy Water Resistance, Good Electricals

*30°/20°C

WRITE FOR SAMPLES AND BULLETIN

THE KEY TO HARCHEM® BETTER PLASTICS

HARCHEM DIVISION

WALLACE & TIERNAN, INC.
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY
IN CANADA: HARCHEM LIMITED, TORONTO

Eastern New England

New Officers Elected

D. V. Rosato (Raytheon Co.)

The following new Officers have been elected by the Eastern New England Section:

President, A. I. Simon; Vice-President, H. C. Cookingham; Treasurer, Dr. R. Ehlers; Secretary, M. Axelrod.

A. I. Simon, new President of Eastern New England Section.

Gim Fong, retiring President of Eastern New England Section.

Other posts filled are as follows: National Councilman, R. L. Mondano; Board of Directors, G. P. Fong, M. Axelrod, H. C. Cookingham, G. Dougherty Dr. R. Ehlers, A. Mascerelli, J. Parker, D. V. Rosato, A. I. Simon, J. Stewart, J. Truitt.

Mr. Fong, member of the Board of Directors, above, is the retiring President of the Section.

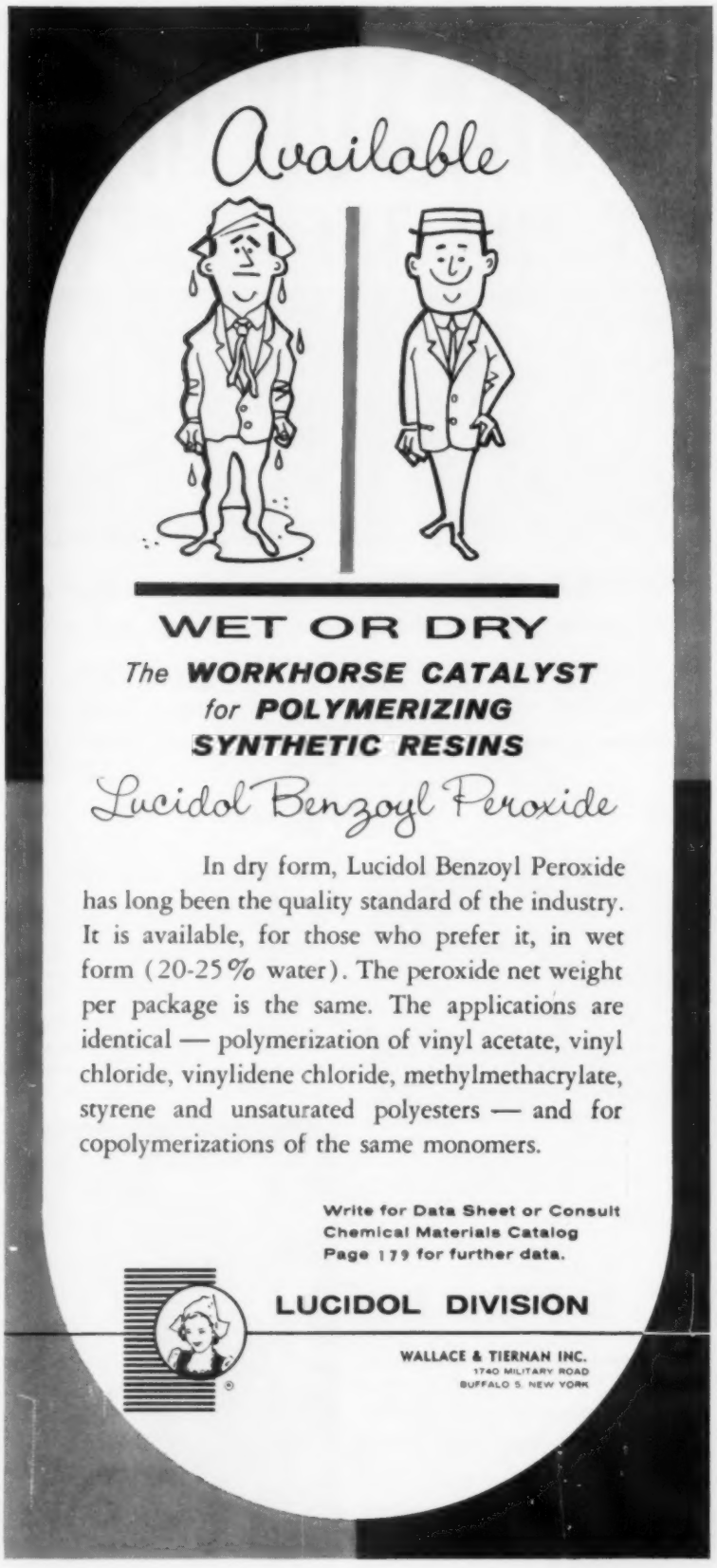
Central Ohio

Talk on Russia

Richard B. Sharpe

(Westinghouse Electric Appliance Co.)

This Section held its annual Ladies' Night program which serves as a kickoff for the coming year's activities. The speaker was Mr. Ernest Fritsche, Columbus businessman who related experiences of his recent 30-day visit to Russia.


Available
WET OR DRY
The WORKHORSE CATALYST
for POLYMERIZING
SYNTHETIC RESINS
Lucidol Benzoyl Peroxide
In dry form, Lucidol Benzoyl Peroxide has long been the quality standard of the industry. It is available, for those who prefer it, in wet form (20-25% water). The peroxide net weight per package is the same. The applications are identical — polymerization of vinyl acetate, vinyl chloride, vinylidene chloride, methylmethacrylate, styrene and unsaturated polyesters — and for copolymerizations of the same monomers.
Write for Data Sheet or Consult Chemical Materials Catalog Page 179 for further data.
LUCIDOL DIVISION
WALLACE & TIERNAN INC.
1740 MILITARY ROAD
BUFFALO 5, NEW YORK

THORESON-McCOSH, INC.

SERVING THE PLASTICS INDUSTRY

HOPPER DRYER and new combination JET HOPPER LOADER

increases your production . . . soon pays for itself in savings to you!

Dries and preheats material at less cost than with conventional drying ovens.

Easy installation in a matter of minutes on any standard machine.

More production because of properly controlled conditioning of material.

Less material handling, with increased hopper capacity, no oven handling.

New Jet Loader maintains preheated condition of material. *No compressed air.*

For complete information write today. THORESON-McCOSH, Inc., 18208 W. McNichols, Detroit 19, Michigan, KEnwood 1-4700

Florida

Florida Leads in Membership Drive

Jack Grosscup (Modern Plastics Co.)

Section meetings will be held on the third Monday of each month at Betty's Restaurant on Biscayne Boulevard. SPE members from other Sections who may be vacationing or living in Miami are cordially invited to attend Florida Section meetings.

Highlights of the meeting of September 9, 1960 were:

1) Presentation of a plastic Aqua-Table to Mr. Al Greenblatt as First Prize in the Inter-Section Membership Drive. Florida Section is leading in National membership drive with a 17.9% increase.

2) Dr. David H. Richman's offer to edit and publish a monthly section newsletter.

3) Showing of the Bell Telephone Company's film "Tools of Telephoning".

North Texas

Personnel Selection

Ernest Dourlet (Cadillac Plastics Co.)

Dr. Hilton D. Shepherd spoke at the monthly meeting of this Section, on September 19. Dr. Shepherd has served as a private consultant to many industries and discussed personnel selection as a management tool.

SPE on the air. Here Bob Craft, left, Fort Worth, PR man and executive secretary of the North Texas Section, interviews Dave Daniels, Section Vice President, over a Fort Worth radio station.

Philadelphia

Foamed Plastics

George R. DeHoff (Du Pont)

The Philadelphia Section began its new season September 27, the first meeting since the very successful June golf outing. President Bob Conwell welcomed over 100 members and their guests to an excellent program on "Foam Technology and Applications." Following last year's very successful "panel" type meeting, three speakers were on hand. Dr. J. Wilson of Atlas Powder Co. discussed Rigid Urethane, Mr. H. Huking of Dow Chemical Co. discussed polystyrene foams and Mr. R. Blomquist, Chairman of the meeting, concluded the series with a discussion and film on flexible urethane foams and their catalysts.

Dr. Wilson explained and demonstrated how rigid urethane foams are made and described their properties and uses. These closed cell foams have found many applications,

especially in areas where their low density and excellent thermal insulating properties can be used.

Mr. Huking reviewed the development of polystyrene foam from its first commercialization during World War II, when it was used in Navy life rafts, until today, when it is being used in many different areas, particularly insulation and packaging.

Mr. Blomquist concluded the series with a discussion of the flexible, or open celled, urethane foams and the catalysts used in their manufacture. Urethane foams are literally expanding all over the world with cushioning being one of the major markets. Their remarks were followed by a film describing the process used to make flexible urethane foams.

Pioneer Valley

Rubber in the Plastics Industry

J. R. Johnston (Foster-Grant)

After a brief summer respite, the Pioneer Valley Section began the new season with a dinner and informative talk by Mr. Otis Bear of the Goodyear Tire and Rubber Company on "Rubber in the Plastics Industry".

In general synthetic rubber is made through the emulsion polymerization of butadiene and styrene with suitable catalyst and arrestors in either a continuous process or a batch process. A heavy slurry is produced which is washed and dried resulting in flakes or crumbs of synthetic rubber. These are then compression packed into bails for shipment. By varying the temperature of polymerization and varying the additives, three different characteristic rubbers are produced; hot cold, and oil extended. Most of the rubber used in plastics is cold rubber because of its better finish and workability.

Discussion centered around many of the difficulties rubber users incur. Some of these problems are as follows:

a. Supply snythetic rubber in particle size to eliminate the chopping or grinding stage.

b. Removal of the excess of arrestors or short stop which hinder the quality of plastic when processed.

c. Reduction of cure time in rubber based materials to facilitate injection molding.

Although a great deal of work is being done on these problems only moderate success has been obtained.

Rochester

Plastics on the West Coast

D. L. Messenger
(Stromberg-Carlson Div., General Dynamics)

The first fall meeting of the Rochester Section was held at Logan's on September 12, 1960.

Speaker of the evening was Mr. Nelce Taylor of Tennessee Eastman Chemical Company, his subject, "Plastics on the West Coast". Mr. Taylor, having been located in Rochester some years ago was well known to the group and many interesting and humorous situations from the past were brought up. His chosen subject proved very interesting and I believe all present were somewhat relieved to hear that in Mr. Taylor's opinion the molders on the west coast have not developed any revolutionary molding techniques, this being somewhat in contrast to rumors occasionally heard in this area. Mr. Taylor's talk was followed by the usual question and answer period.

There were 60 members and guests present.

Size and separate your materials the modern way with these rotary motion Simon-Carter machines

The *rotary* motion principles employed in Simon-Carter machines are far more efficient and accurate than flat surface screening methods. For length sizing or separating, pockets or indents are used. For thickness or width sizing or separating, perforated cylinders (*that stay clean*) are used. All machines are compact in relation to capacity, and are of all-metal construction. Write today for complete information and descriptive booklets. Free laboratory testing and demonstrating service.

CARTER SCALPERATOR
Coarse materials are carried over the top of a rotating wire mesh screen. Fine materials are drawn out by suction. The Carter Scalperator is used for cleaning material as it is shipped or received. Another all-rotary-motion machine.

CARTER PRECISION GRADER
Separates and sizes free-flowing granular materials by *thickness* and *width* differences.

CARTER DISC SEPARATOR
Unexcelled for accurately separating and sizing free-flowing granular materials by *length* differences.

WRITE FOR COMPLETE INFORMATION

SIMON-CARTER CO.
695 19th Avenue N. E. • Minneapolis 18, Minnesota

Successful end results

depend on controlled

COLOR

PIGMENTS

application-tested

• Cadmiums • Mercuries

• Organics • Inorganics

Kentucky Color

AND CHEMICAL COMPANY, INC.

DIVISION OF THE HARSHAW CHEMICAL COMPANY 600 NORTH 34TH ST., LOUISVILLE 12, KY.

NEW BOOKS

METALLIZING OF PLASTICS

Harold Narcus, Reinhold Publishing Corp., New York, Published 1960. 208 pp. $5.50.

Here is a good book, one of the few that are technically informative without being technically deep and complex. It is excellent for readers who want to find out how one or more metallizing processes are performed. It discusses each process in turn—describing the necessary equipment *and* the proper techniques of operation. And it is aimed squarely at the man with little metallizing experience who has to actually supervise a metallizing operation. It is a fine general training manual.

Mr. Narcus is obviously an expert in this field. His writing is full of practical helping hints and comments—simple for the man with experience but unknown to the newer entrant. For example, "an aluminum film . . . 2 to 3 millionths of an inch will completely conceal the color of the basis material", and "the cost of vacuum metallizing (such) sheet stock . . . varies from . . . 5 to 8 cents/square foot." Surely, other experts will disagree with some of his comments—in this industry no one is always sure or right—but the book isn't written for them. The many who feel that a qualified opinion is better than hedging or polite silence, and who need that opinion in their work, will find it in this book. Mr. Narcus is to be commended for talking to his readers on a useful, practical level.

Illustrations and diagrams are adequate in number and quality. There are some typographical errors, including a few of a technical nature. The book is short (198 pp. text); especially so, considering the many pictures and the small pages (5" x 7-¾"). However, it is so full of facts and comments that one must read quite slowly to understand it.

Allan L. Griff
Union Carbide Plastics Co.
Technical Service

POLYTHENE

(The Technology and Uses of Ethylene Polymers) 2nd Edition. Edited by: A. Renfrew and Phillip Morgan, Interscience Publishers, Inc., 746 pp. $25.75.

The second edition of "Polythene" like the first is a collection of chapters on various aspects of the manufacture, properties, fabrication, and uses of polyethylene written by recognized authorities in their fields. The new edition is larger by four chapters and 200 pages, is better organized, and is significantly broader in coverage. Most of the original chapters have been rewritten, duplication has largely been eliminated, and the book now includes a vast amount of information on high-density polyethylene. For example, good descriptions of three of the more important processes for the manufacture of high-density polyethylene are given. A chapter containing an excellent discussion of the kinetics of ethylene polymerization by the Zeigler catalysts has been added, although nothing could be found on the kinetics of the Phillips or Standard Oil of Indiana processes.

Other important additions include an excellent chapter on ethylene copolymers and blends, two chapters on packaging outlets other than film, a chapter on vacuum forming, and one on the reprocessing of scrap. Major revisions have been made in the chapters on irradiation, general mechanical properties and low molecular weight polyethylene.

With very few exceptions the various authors have provided numerous references, while tables, graphs, and photographs are used liberally. The book is very well indexed, both by subject and by author, and appears to be remarkably free of typographical errors. Although the price is high, this reviewer was most favorably impressed, and believes that "Polythene" should be very useful to anyone concerned with this important and rapidly-growing plastic material.

E. E. Lewis
Du Pont Co.

"Our BIPEL Preform Rate jumped from 1900 to 3300 per hour!"
So reports General Industries Co., Elyria, Ohio . . . on their new BIPEL Horizontal Hydraulic Preformers. Leading producers everywhere are praising these faster, more flexible units. Are you getting maximum results? Write for complete information.
Demonstrations and Services at Tiverton
B.I.P. Engineering Ltd. Sutton Coldfield, England
RALPH B. SYMONS ASSOC., INC. 3571 Main Road, Tiverton, R. I.
BIPEL®
COMPRESSION - TRANSFER PRESSES
HORIZONTAL HYDRAULIC PREFORMERS

PLASTICS AROUND THE WORLD

This month's column has been made possible through the contributions of these abstracters:

Alexander Baczewski (L'Officiel des Matières Plastiques and Pensez Plastiques)

Geza Gruenwald (Kunststoff-Rundschau)

R. George Hochschild (Kunststoffe and July Kunststoff-Rundschau)

Alfred L. Alk (Poliplasti)

T. Wold (Plastic)

J. B. Wolheim (Tworzywa Guma Lakiery)

France

L'OFFICIEL DES MATIERES PLASTIQUES

JULY-AUGUST 1960

Non-Supported Films—pp 556-559

Solutions of resins are extruded and then dried by floating upon molten alloys or salts. This process ensures glossy surfaces and a minimum of stresses. Vinyl films are made from plastisols. Poly-(vinylalcohol) solutions have to be gelled before drying. Many phenols and various dyestuffs are used for this purpose. Methyl methacrylate is polymerized in plate glass molds under exclusion of air. (33 refs.)

Polymers Containing Silicon—pp 565-570

A list of 323 French patents from 1946 to 1957. (To be continued.)

PENSEZ PLASTIQUES

MAY 1960

(Special issue #82) Proposed Acceptance Specifications for Polyethylene as Used for Pipes—pp 61-65

The resin will be tested as to tear strength and elasticity, stress-cracking in MEK, dispersion of carbonblack, meltindex and specific gravity.

(Special issue #192) Report from Expomat—pp 14-18

The Exhibition of Building Materials in Paris (EXPOMAT) has shown many contributions of the plastics industry. Polyester panels set in epoxy mortar and neoprene gaskets find a ready market. Expanded polystyrene, one side laminated to corrugated aluminum and the other to asbestos board, is used for curtainwalls. Roofs are fabricated from rigid PVC, skylights from acrylics. A cinderblock having a plastic face has been shown. PVC pipes and vinylclad coppertubing are used to replace lead and iron.

A Self-supporting Window Made of Plexiglas—pp 20-21

Windows of the "French" type are molded in one piece, their frame using a new boxlike design. They weigh 15 pounds only and swing into the apartment for easy cleaning.

FIRST QUARTER 1960

(Special issue #187) Entire issue devoted to packaging

This is a special issue devoted to packaging. Illustrations show e.g. foamed polystyrene for dates and for perfume bottles, polyethylene for bananas, cellulose acetate boxes for candies and for orchids.

(Special issue #195) Plastic Packaging and the Preservation of Apples and Pears—pp 25-28

An amply documented treatise on the influence of the permeability of a plastic film upon the keeping qualities of various kinds of pears and apples. Almost every variety of fruit prefers another equilibrium of moisture and atmosphere, and a film should only be recommended for the packaging of a fruit after exhaustive testing.

The Shaping of Plastics by Machining—pp 29-32

A description of tools which are used for the machining of plastics and their modes of operation. Detailed recommendations for the shaping of rigid PVC, Plexiglas, Nylon, Teflon, and Fel-F follow. The importance of the thermoplasticity for success and failure of machining is amply stressed.

Germany

KUNSTSTOFF-RUNDSCHAU

JUNE 1960

Reports on Two Outstanding German Fairs—21 pages

The reports (21 pages in this issue) on the Hannover German Industry-Fair and the Duesseldorf Interpack (International Packaging Fair) should be pointed out to readers who are interested in the latest European developments of the plastics industry.

JULY 1960

Structural Components Containing Styropor Expanded Plastics—pp 317-20

The article illustrates the use of styropor, the expanded polystyrene produced by BASF as a material of construction. The paper contains data on the general properties of three types of styropor and quantitative data concerning the properties of various structural components and parts which contain, as part of their composition, various types of Styropor. Discussed are plates made from lightweight aggregates, panels used for insulation in flat roof construction and panels used for outside curtain walls. Eleven illustrations indicate the extensive use to which the expanded plastic has been put in the architectural field.

Applications for Room Temperature Curing Expanded Thermosets—pp 323-25

ISOSCHAUM, a room temperature curing urea-formaldehyde expanded thermoset, produced by Schaum-Chemie W. Bauer AG, has been tested for six years for use as an insulation material for fuel gas conduits. Details on the mechanical properties and the vibrational characteristics are presented. A number of illustrations show the burning characteristics of the material. The paper describes further a method of installation of insulated gas pipes surrounded by the foam and expanded metal lattices.

Thermoforming Applications from Polypropylene Sheets—pp 313-319

The method of forming small, thin-walled containers is described. Polypropylene sheets, made from the lightest of all thermoplasts which is hard but brittle, possess excellent gloss and excellent forming properties, surpassing even low pressure polyethylene sheets. Containers made from polypropylene shrink considerably less than those made from low pressure polyethylene. The transverse and parallel shrinkages are equal. This

enables the fabricator to work with smaller final tolerances. The paper contains many illustrations describing the various applications possible with thin-walled, thermoformed containers made from polypropylene. It further contains many practical hints on the preparation of such pieces. Three methods of vacuum forming polypropylene sheets are described: (1) the straight method of vacuum forming, (2) the drape method without mechanical prestretching, and (3) the plug method with mechanical prestretching.

KUNSTSTOFFE, Vol. 50

JULY 1960

Reinforced Ziegler Polyethylene Pipes—p 371

Thermoplastic materials can be reinforced or strengthened by subjecting them to stretching at elevated temperatures. This characteristic has so far only been utilized in the field of synthetic fibers and film. The present article deals with a new process whereby Ziegler polyethylene pipes are biaxially stretched and thereby strengthened. Such pipes have twice the creep strength of ordinary pipes made of the same material and thus require to be only half the wall thickness.

Chemical Reactions of Polystyrene—p 375

Polystyrene is a fairly unreactive polymer. It is however possible to carry out a series of substitutions under certain conditions, followed by further reactions. Such polystyrene derivates have sometimes proved useful for practical purposes. By reaction with iodine and subsequent substitution of the iodine by lithium, one obtains poly-p-lithium styrene, a substance which is extremely reactive and can be converted into a number of interesting derivates of polystyrene. Finally, the author discusses a number of reactions involving polystyrene which can be used for making graft polymers.

Mechanical Strength of Polyester Mouldings in Relation to Curing Rate and Type—p 388

In the production of glass fiber/polyester laminates by the hand lay-up process, the vacuum method or cold moulding one is restricted to cold setting. This paper deals with the question as to how maximum mechanical strength can be attained in relation to the catalyst system and curing time. The results of the experiments show that final tempering exerts a considerable influence.

Behavior and Properties of PVC Floor Coverings—p 417

The common brands of PVC floor covering are classified according to their behavior in use in order to enable both the architect and the user to make the best possible use of these materials. The individual properties of the floor coverings examined were determined using standard test methods.

Poland

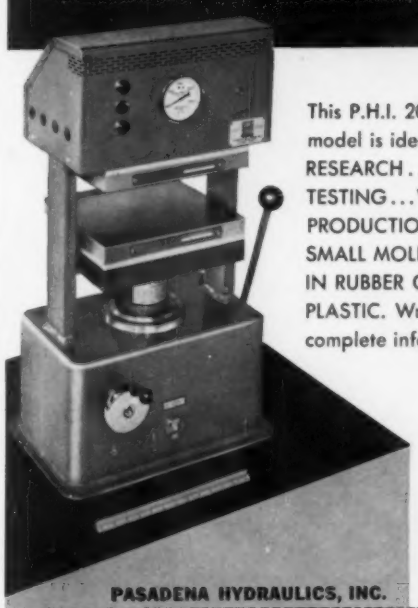
TWORZYWA GUMA LAKIERY

APRIL 1960

Determination of the Structure of Polyethylene by the Use of Infra-Red Absorption—(authors Teresa Biernacka and Barbara Kontnik)

In a series of three articles the authors discuss the use of infrared methods for the determination of branching, unsaturation, and the

CADET
ORGANIC PEROXIDES
BENZOYL PEROXIDE
LAUROYL PEROXIDE
2, 4 DICHLOROBENZOYL PEROXIDE
TERTIARY BUTYL HYDROPEROXIDE
METHYL ETHYL KETONE PEROXIDE
Your Assurance of the Highest Uniform Performance
Prompt Shipment from Warehouse Stocks in Principal Cities
Distributed by
CHEMICAL DEPARTMENT
McKesson & Robbins, Inc.
Dept. SJ, 155 East 44 Street
New York 17, New York
Manufactured by
CADET
CHEMICAL CORP.
Burt 1, New York
Write Now! A local McKesson & Robbins Chemical Department representative will be pleased to call and talk over your Organic Peroxide requirements.

ACCURATE DATA!

This P.H.I. 20 Ton model is ideal for... RESEARCH... TESTING...VOLUME PRODUCTION OF SMALL MOLDED ITEMS IN RUBBER OR PLASTIC. Write for complete information.
PASADENA HYDRAULICS, INC.
1432 Lidcombe, El Monte, Calif.
P·H·I
PRESS

YOU ASKED FOR IT!
WE PIONEERED IT!

"HIGH SPEED—TROUBLE-FREE INDUCTION HEATED DIES THAT INSURE UNIFORM HEAT— FAST HEAT-UP TIME AND AT 50% LESS POWER CONSUMPTION"

If you are not satisfied with conventional dies, you should investigate! We will be glad to quote on proven dies for the production of free film, blown film or for coating and laminating.

INDUCTION HEATED

FILM & COATING

DIES

for On Stream production

Address inquiries to

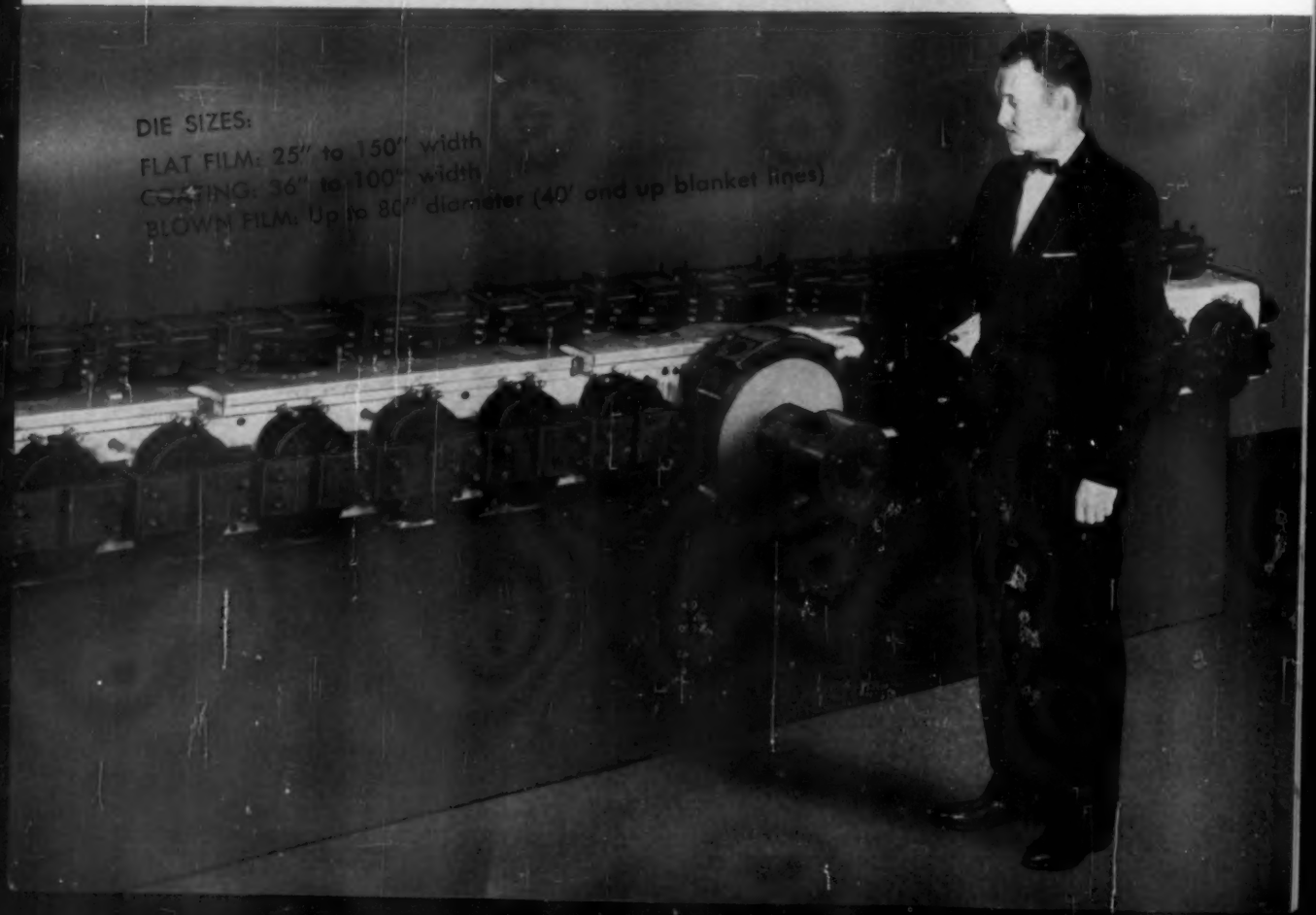
HALE AND KULLGREN INC.

613 E. TALLMADGE AVE., AKRON, OHIO

BLAW-KNOX

Aetna-Standard Division

BLAW-KNOX



degree of crystallinity in polyethylene. Illustrations are given of infrared absorption spectra in various regions of different samples of polyethylene. The authors discuss the absorption bands of polyethylene which had been exposed to ultraviolet light. The absorption bands of polyethylene samples in various molecular weights are also given.

The article also describes a detailed method for the determination of the degree of crystallinity in polyethylene by infrared absorption. The degree of crystallinity is calculated from the ratio of infrared absorption at 7.625μ of a polyethylene sample at room temperature to its maximum absorption value near the melting point. The article publishes a list of the degree of crystallinity calculated by this method for various samples of high pressure and low pressure polyethylene.

The method of infrared absorption is also used for the determination of branching. This is done by calculating the intensity of infrared bands characteristic of CH_3 groups and CH_2 groups. The authors describe in detail how this method was used in measuring the degree of branching in domestic and foreign samples of polyethylene.

Determination of the Molecular Structure on the Properties of the Polymer—(author—Maria Gorska)

The author discusses the molecular structure of polyethylene such as chain length, branching, and methyl groups. These properties will effect the degree of crystallinity of the polymer.

The article describes briefly the various methods used in determining the degree of crystallinity of polyethylene. These methods are X-ray diffraction, infrared absorption, and microscopic analyses. Included in this article is a table comparing the physical properties of high density and low density polyethylene. A graph is also presented indicating in a polymer the relation between the general properties, type of polyethylene, average molecular weight, and degree of crystallinity.

Denmark

PLASTIC

APRIL 1960

Danish Production of Polyethylene—pp 96-99

Maersk Refinery in cooperation with Imperial Chemical Industries Limited in England will start production of polyethylene in Denmark. When the new plant is ready in a couple of years it will employ approximately 200 men. It will cost in the neighborhood of 12 million dollars which is divided equally between Maersk and I.C.I. The name of the new undertaking will be Danbritkem A/S and the capacity will be 15000 tons per year which is about three times the Danish import up until now.

Polyethylene Oil Can—p 122

The article reports abuse of jerry cans made from polyethylene to carry spare gasoline in the baggage compartment of cars. In some cases gasoline vapours filled the compartment and in other cases on hot days the jerry can would split open. The editor wants the authorities to take steps to prevent such mis-use of plastic materials.

for your finishing operations

ACROLEAF© Hot Stamping Machines

accomplish the *QUICK* Color Marking and Decorating Operations on your molded and fabricated plastic parts and products.

- Plenty of open area for work and standard or special fixtures.
- Widely adaptable. Semi-Automatic.
- Electronic controls. Power from your shop air-line.
- Automatic tape feed.
- No protruding parts.
- Multi-color work can be handled.
- Well engineered scientific construction.
- Low price and operating cost.

ACROLEAF© Model 250

Write today for Catalog 54HS with Price List. Send details of your need for Engineer's assistance.

ACROMARK

THE ACROMARK COMPANY

365 MORRELL ST., ELIZABETH, NEW JERSEY

"PLASTIC MARKING PIONEERS"

"The Original Marking Specialists"

TECHNICAL MEETINGS CALENDAR

17th ANTEC

Annual Technical Conference—January 24-27, 1961, Shoreham and Sheraton Park Hotels, Washington, D.C. Sponsored by the Baltimore-Washington Section. General Chairman: Dr. Gordon Kline, National Bureau of Standards, Washington, D. C.

1960 RETECS

November 7—Automation in Injection and Compression Molding, Ontario Section; King Edward Sheraton Hotel, Toronto. Chairman: J. M. Lees, c/o Canadian General Electric Co., 755 Division St., North Cobourg, Ontario, Canada.

November 18—Blow Molding, Newark Section; Essex House, Newark, N. J. Chairman: Robert Hoehn, Mack Molding Co., Ryerson Ave., Wayne, N. J.

1961 RETECS

April 25, Indianapolis, Ind., Central Indiana Section; **Plastics for Tooling.** Section President: Milton Brummer, 4241 Marrison Place, Indianapolis, Ind.

May 9, Detroit, Mich., Detroit Section; **Plastics in the Automotive Industry.** Section President: John D. Young, E. I. du Pont de Nemours & Co., Inc., 13000 West Seven Mile Rd., Detroit 35, Mich.

October, Niagara Falls, N. Y., Buffalo Section; **Foams.** Section President: William Dunmeyer, Carborundum Co., Buffalo Ave., Niagara Falls, N. Y.

Offers of papers for presentation at these Regional Technical Conferences are invited. Please address offers to Section Presidents, as indicated above.

SPI EVENTS—1961

February 7, 8, 9—Sixteenth Reinforced Plastics Division Conference, The Society of the Plastics Industry, Inc., Edgewater Beach Hotel, Chicago, Ill.

April 20, 21—Eighteenth Annual SPI Western Section Conference, The Society of the Plastics Industry, Inc., Hotel del Coronado, Coronado, Calif.

June 5-9—Ninth National Plastics Exposition, Sponsored by The Society of the Plastics Industry, Inc., Coliseum, New York City.

June 5-9—SPI National Conference, Sponsored by The Society of the Plastics Industry, Inc., Commodore Hotel, New York City.

POLYMER SYMPOSIUM

July 27-August 1, 1961, International Symposium on Macromolecular Chemistry, Montreal, Canada. Address inquiries to: The Organizing Committee International Symposium on Macromolecular Chemistry, P.O. Box 816, Sarnia, Ontario, Canada.

SOUTHEASTERN NEW ENGLAND SECTION TECHNICAL PROGRAM

November 15—Use of Visual Means for Study of Extrusion Flow Patterns Ernest C. Bernhardt, Head Process Development, Technical Service Laboratory, Polychemicals Department, E. I. DuPont de Nemours & Co.

January 17—Plastics in Building Dr. Frederick J. McGarry, Associate Professor of Materials, Massachusetts Institute of Technology, Cambridge, Massachusetts.

February 21—Blow Molding Techniques Robert J. Boyden, F. J. Stokes Corporation, Stamford, Connecticut.

March 21—The Future of Thermoset Molding J. B. Lidstone, Specialist, Market Development, Phenolic Product Line, General Electric Company, Pittsfield, Massachusetts.

April 18—Thermal Consideration in Mold Design W. J. B. Stokes, Electromold Corporation, Trenton, New Jersey.

for information, contact Mr. Samuel N. Greene, Program Chairman, c/o Apex Tire & Rubber Co., Pawtucket, R. I.

SPE to Co-Sponsor ASTME Tooling Seminar

SUGGESTED OUTLINE PROGRAM

Through its Casting and Plastics Tooling Professional Activity Group, SPE will co-sponsor with the American Society of Tool and Manufacturing Engineers, a Seminar on "Plastics for Tooling", March 15-16, 1961, Hotel Statler, Detroit, Michigan.

SPE's participation will consist in assisting in the development of the technical program and in publicizing the Seminar among its members and to the plastics industry. All other meeting functions including finances are the sole responsibility of ASTME.

SPE members are eligible for the $45 member registration fee instead of the $60 non-member fee.

CPTPAG Chairman Lawrence Wittman is heading up SPE's contributions to the technical program. Offers of papers for the technical program not only are most welcome but are cordially solicited by Mr. Wittman. A suggested outline program follows below.

No papers have been committed for the program to date, and the subjects listed are suggestions only. Any paper offered in the general field of plastics for tooling will be considered for the program if received before December 5. Mr. Wittman's address is c/o L. Wittman & Company, 1395 Marconi Blvd., Box 69, Copiague, L. I., N. Y.

March 15, 1961

8:30-9:30	—Registration & Coffee Hour
9:30-12:00	—Applications of Plastics for Tooling
Paper 1.	Factors of Economy in Plastics for Tooling
Paper 2.	Design Considerations in Plastics for Tooling
Paper 3.	Tooling Applications Stampings Forming Assembly
12:00-1:30	—Lunch
1:30-3:00	—
Paper 4.	Laminate Structures
Paper 5.	Mass Casting
3:00-3:15	—Coffee Break
3:15-5:00	—
Paper 6.	Tooling for Mass Production
Paper 7.	Tooling for Small-Lot Production

March 16, 1961

9:00-12:00	—
	Tour of Manufacturing Plant Plastic Tools and Dies Mass Casting
12:30-1:30	—Lunch
1:30-3:30	—Open Forum Panel Discussion Discussion period based on all papers and plant tour
3:45	—Adjournment

Employment & Service Guide

POSITIONS OPEN

POLYMERIZATION CHEMIST

Ph.D. or M.S. Chemist with 5-10 years of experience in plastic and/or paint formulations. Exceptional opportunity to advance with expanding research group. Position is at our New Brunswick, New Jersey Laboratory. Please send resume of education, experience, and salary requirements to:

Personnel Department
CARLISLE CHEMICAL WORKS, INC.
Reading 15, Ohio

PLASTIC MATERIALS APPLICATIONS ENGINEER

Opening in Plastic Materials Applications Engineering. Degree in Chemical Engineering or Chemistry required. At least three years specification and design or equivalent heavy practical experience in thermoplastic and thermosetting molding techniques and materials necessary. Experience in adhesives and rubber technology desirable. Work to include in-company consulting service to design engineers to assist them with plastics problems. Liberal company benefits. Relocation expenses paid. Send resume to

R. J. Anderson
REMINGTON RAND UNIVAC
Division of Sperry Rand Corporation
Univac Park—St. Paul 16, Minnesota

CHEMICAL OR MECHANICAL ENGINEER

We have an interesting and challenging position available immediately in our Reading, Pennsylvania plant for a man with at least two years experience and training in the plastics industry. Background in the compounding of Vinyls, Epoxies or Phenolics is desirable. Duties will consist of process development and production supervision. This position is in line with a revolutionary new coating method, and offers unlimited opportunities for advancement.

Please send resume in confidence to:

THE POLYMER CORPORATION
P./O. Box 422
Reading, Pennsylvania

POLYMER CHEMIST

Excellent opportunity for top-rate organic chemist with experience in thermosetting resins; to work on unique problems in epoxy, phenolic, and chemical intermediate development. Want management potential individual to join young group of researchers in growing, imaginative company. Boston suburb location. Please send résumé and salary requirements to Box No. 9560, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

MOLDMAKERS

Two experienced men required for our toolroom. Must be able to construct complete injection molds from drawings or samples.

Reply:
PEARCE-SIMPSON, Inc.,
Molded Plastics Div.,
P.O. Box 48-223,
Miami 42, Florida.

PLASTICS ENGINEER

Thorough knowledge of injection molds; tool design, maintenance, and trouble shooting. Salary commensurate with ability. Contact: Jerry Lerman, Multiple Products Corporation, 55 West 13th Street, New York 11, New York.

DEVELOPMENT CHEMISTS

We have three openings in our development labs for young aggressive chemists. Three to five years industrial experience preferred. Condensation polymers, rubber chemicals, and epoxy backgrounds of interest. New England location. Send résumé and salary requirements. Box No. 9660, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

PLASTICS ENGINEER

To manage small plastics operation of southern machinery manufacturer. Processes include compression and injection moulding of plastic and synthetic components. Several years experience is needed. Must be able to originate practical designs to function on machines. Please send complete details of specific background for immediate reply. Age: 30-40. Box No. 8960, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

POSITIONS WANTED

ACTIVE DEVELOPMENT ENGINEER, age 50. Strong and diversified industrial background and extensive knowledge. Desire position with very progressive firm for research and development of advanced and new spray-building equipment and techniques. Resume sent upon request. Box No. 9260, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

BLOW MOLDING AND EXTRUSION SALES MANAGER

Available immediately to locate anywhere. Sales experience in blow molding industrial parts and custom extruded shapes. 3 years as chemist, 4 years as product manager, 5 years in sales. Presently employed in executive capacity with a blow molding company. Box No. 9160, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

SENIOR RUBBER & PLASTICS TECHNOLOGIST

Background in R & D, Quality Control, Process Engineering, Plant Management, Technical Sales Service, Market Analysis, Sales Promotion. Familiar with chemistry, compounding, and application of natural and synthetic lattices and rubbers, epoxies, polyesters, urethanes, vinyls. Reply Box No. 7800, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

MOLDER

Diversified practical experience in compression and injection molding. Have eleven years experience as molder, set-up, trouble shooting, quality control, tooling and setting up of systems and procedures conducive to good molding practice. Desire relocation with position in a progressive company. Resume sent on request. Box No. 9760, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

CLASSIFIED RATES

"Position Open" and "Position Wanted"—$12.50 per column inch, 2¼ inches wide. (35 characters per line; 7 lines per inch). Minimum charge: $12.50. "Products and Services"—$20.00 per inch. Minimum charge: $20.00.

All ads include one bold face caption line. Additional caption lines at $2.50 extra per line. Boxed ads (four side rules) $3.00 additional charge. Agency commission allowed *only* on ads five inches or more in depth. Display ads of 1/6 page or more are charged at regular advertising space rates. Typesetting (non-commissionable) will be charged as cost.

SPE members in good standing are entitled to a total of three no-charge "Position Wanted" advertisements during any twelve month period, each ad not to exceed 50 words, headline not to exceed 3 words.

Last day for inserting ads is the first day of the month preceding date of publication. Employers please note: The SPE Journal does not have resumes on file. These must be requested from the applicant.

POSITIONS WANTED

ENGINEER

Mature engineer (early 30's) wishes position around Detroit metropolitan area. 12 years of experience in plastic injection molds and die cast dies. Experience in supervision, estimating, purchasing, trouble shooting, liaison, and some designing. Practical shop experience as a die maker. Member of technical societies; posesses current pilot's license. Box No. 9460, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

SENIOR PRODUCTION ENGINEER

Nine years experience in all phases of plastic laminating, molding and bonding, from directing laboratory test programs through production shop assistance. Currently responsible for proper design applications, general sales support on design feasibility and quotation, and production liaison and assistance. Desire responsible position in North, Central or Eastern U.S. Reply Box No. 9360, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

PLASTICS ENGINEER

Advanced degree and ten years of industrial experience. Patents and publications. Desire a responsible position where a broad background in thermoplastics including processing, research, product development, sales liaison, and technical service can be fully utilized. Box No. 8460, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

TECHNICAL SERVICE-SALES

Chemist & Engineer, young. Presently employed in thermosetting resin lab. doing evaluations, development, application, and tech. service. Familiar with potting, encapsulation, tooling, molding. Desires position in tech. service and/or sales in Western Pennsylvania area. Excellent background with 7 years in plastics. Resume furnished. Box No. 8260, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

PRODUCTS & SERVICES

WANTED

Used, late model 4½" plastic extruder, 21/1 ratio. Minimum 50 HP. Will pay top price for immediate delivery. Will consider late 3½" 21/1 ratio. Reply Box #9960, SPE JOURNAL, 65 Prospect St., Stamford, Conn.

Advertisers' Index

The Acromark Co. 1257
Aetna Standard, Div. Blaw-Knox Co. 1274
Allied Chemical Corp.—National Aniline Div. 1186
Allied Chemical Corp.—Plastics Div. Cover 2
Archer-Daniels-Midland Co.—Plastics Div. 1228
Argus Chemical Corp. 1230
Barber-Colman Co.—Wheelco Div. 1229
B.I.P. Engineering Ltd. 1271
Blaw-Knox Co.—Aetna Standard Div. 1274
Cadet Chemical Corp. 1273
Celanese Polymer Co. 1197, 1198
Detroit Mold Engineering 1205
Dow Chemical Co.—Coatings 1257
E. I. Du Pont de Nemours & Co.—Polychemicals Div. 1184
Eastman Chemical Products, Inc.—Plastics Div. 1182, 1188, 1189
Emery Industries, Inc. 1255
Farrel-Birmingham Co., Inc.—Watson Stillman Press Div. 1208, 1209
Ferro Corp. 1256
Gering Plastics, Inc., Div. Studebaker-Packard Corp. Cover 4
B. F. Goodrich Co., Geon Div. Cover 3
W. R. Grace & Co., Polymer Chemicals Div. 1210
Harchem Div., Wallace & Tiernan, Inc. 1266
Improved Machinery, Inc. 1220
Industrial Research Laboratories 1261
Injection Molders Supply Co. 1192
Kentucky Color & Chemical Co. 1270
Lucidol Div., Wallace & Tiernan, Inc. 1267
Monsanto Chemical Co.—Organic-Plasticizers 1258, 1259
Monsanto Chemical Co.—Plastics 1226, 1227
H. Muehlstein & Co., Inc. 1262
National Aniline Div., Allied Chemical Corp. 1186
National Distillers & Chemical Corp.—U.S. Industrial Chemicals Co., Div. 1203, 1204
National Lead Co. 1191
National Rubber Machinery Co. 1206
Package Machinery Co.—Reed-Prentice Sales Div. 1196
Pasadena Hydraulics, Inc. 1273
Plastics Engineering Co. 1190
Reed-Prentice Sales Div.—Package Machinery Co. 1196
Reichhold Chemicals, Inc.—Plastics 1217
Simon-Carter Co. 1269
Spencer Chemical Co. 1194, 1195
Sterling, Inc. 1187
Thoreson-McCosh, Inc. 1268
Trico Blow Molding Corp. 1185
Union Carbide Plastics Co., Div. Union Carbide Corp. 1218, 1219, 1263
U.S. Borax Research Corp. 1181
U. S. Industrial Chemicals Co., Div. of National Distillers & Chemical Corp. 1203, 1204
Wallace & Tiernan, Inc.
Harchem Div. 1266
Lucidol Div. 1267
Watson-Stillman Press Div., Farrel-Birmingham Co., Inc. 1208, 1209
West Instrument Corp. 1265

Another new development using

B.F.Goodrich Chemical *raw materials*

New Push-Button Heating Pads by General Electric have five parts made of Geon shown in inset: (1) inner cover; (2) cordset; (3) T-Connector; (4) tube which contains thermostat; and (5) heater wire insulation. B.F.Goodrich Chemical Company supplies the Geon vinyl.

How heating pads get "most wanted" features from different Geon vinyls

Waterproof. The manufacturer of these heating pads says they "make wet pack applications a cinch." The reason? Their inner cover is made of film extruded of Geon vinyl. It is tough, abrasion-resistant and waterproof.

Convenient. Three thermostatically-controlled heats are at fingertip in a push-button switch with a cordset which is accurately molded of another form of Geon vinyl. The thermostat connections are enclosed in tubing made of a similar impact-resistant, rigid-type Geon. These vinyls are white—could be any color.

Safe. All the wiring inside the heating pad is insulated with still another Geon vinyl. Geon provides excellent dielectric properties and good resistance to abrasion, weathering and heat, as well as being unaffected by corrosion.

Here is an excellent example of the way one manufacturer uses different Geon resins and compounds to improve a product. For more information, write Dept. GM-6, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

Geon VINYLS

B.F.Goodrich Chemical Company
a division of The B.F.Goodrich Company

B.F.Goodrich

GEON vinyls • HYCAR rubber and latex • GOOD-RITE chemicals and plasticizers

FROM MISSILES TO MISSILES...

GERING Thermoplastic MOLDING COMPOUNDS

quality formulated to perform as required!

Roaring down the Atlantic test range or blasting off from the living room floor, true missile performance depends on the accurate behavior of individual components. That's where Gering's expert ability to formulate superior thermoplastic Molding Compounds comes in. Whether the end use is a vinyl jacketing compound that helps trigger a giant ICBM into space or an impact styrene toy replica, quality Gering Molding Compounds perform to perfection. Extensive laboratory and production facilities enable Gering to produce to your most exacting specifications — including flame-retardant, non-toxic, static-conductive and other special formulations. And with these complete facilities at your service, your most demanding custom compounding requirements can always be met. Tell us your specific needs. We'll be happy to submit a recommendation at no obligation. Write today for information.

• Polyethylene • Vinyl • Styrene • Impact Styrene
• Acetate • Nylon • Acrylic • Styrene Copolymer • Butyrate

Cable Address: GERING • TWX Cranford, N.J. 137 • Sales Offices: 5143 Diversey Ave., Chicago 39, Ill.
1115 Larchwood Rd., Mansfield, Ohio • 103 Holden St., Holden, Mass.

GERING
PLASTICS
division of STUDEBAKER-PACKARD CORP.
Kenilworth, N.J.